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REPORT

ON THE

DANISH OCEANOGRAPHICAL EXPEDITIONS 1908-1910

TO THE

MEDITERRANEAN AND ADJACENT SEAS

PUBLISHED AT THE COST OF THE CARLSBERG FUND

UNDER THE SUPERINTENDENCE OF

JOHS. SCHMIDT, PH. D.

DIRECTOR OF THE CARLSBERG PHYSIOLOGICAL LABORATORY, COPENHAGEN,
MEMBER OF THE DANISH COMMITTEE FOR THE STUDY OF THE SEA,
LEADER OF THE EXPEDITIONS

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VOL. II: BIOLOGY

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TO THE MEDITERRANEAN AND ADJACENT SEAS
Vol. II. Biology.

A. 1.

Flat-Fishes (Heterosomata)

by

H. M. Kyle, D. Sc.

With 4 Plates, 7 Charts and 30 figures in the text.

Published June 25th 1913.

CONTENTS

page

I. Introduction ... 3
a. Material ... 3
b. **Rhombus,** a question of nomenclature ... 8
c. Classification of the European genera and species of **Rhombidae** ... 11
d. Tables showing the records of the hauls of postlarval flat-fishes made by the "Thor" in the Mediterranean and adjacent waters, 1908—10 ... 16
II. Subfamily **Bothinae** ... 22
A. Genus **Arnoglossus** ... 22
a. Historical summary ... 22
b. Specific characters of **Arnoglossus** ... 27
c. Summary of the adult and postlarval characteristics distinguishing the species of **Arnoglossus** ... 49
1. *Arnoglossus Grohmanni* (Bonap., non auctorum) ... 51
2. — *Thori* nov. nom. ... 55
3. — *laterna* Will. ... 64
4. — *imperialis* (Raf.) ... 79
5. — *Rüppeli* (Cocco) ... 87
B. Genus **Bothus** ... 94
Description of the postlarval development in the Genus **Bothus** (*B. podas, B. atlanticus* etc.) ... 97
1. *Bothus podas* (Delar.) ... 100
2. — *atlanticus* n. sp. ... 105
III. Family **Soleidae** ... 115
1. *Solea angulosa* Kaup ... 116
2. — *vulgaris* Quens. ... 117
3. — *azevia* B. Capello ... 118
4. — *ocellata* L. ... 119
5. — *capellonis* Steind. ... 119
6. — *variegata* Don. ... 121
7. — *lutea* Risso ... 122
8. — *monochir* Bonap. ... 123
9. — *Kleini* Risso ... 124
10. — *lascaris* Risso ... 126
11. — *nasuta* Pallas ... 127
IV. Family **Cynoglossidae** ... 128
Genus **Symphurus** ... 128
1. *Symphurus lactea* (Bonap.) ... 130
2. — *ligulata* (Cocco) ... 138
V. Appendix: Description of some postlarval specimens of flat-fish from the North Atlantic ... 140
Literature references ... 147
Description of figures ... 149

I. INTRODUCTION

a. MATERIAL

The postlarval material consists mainly of the collections made by the "Thor" in the Mediterranean and neighbouring waters during the winter of 1908—09 and the summer of 1910. Further, the surface collections made by various Danish vessels in the Mediterranean and Atlantic during the years 1911 and 1912 have contributed to swell the number both of species and specimens. In addition, the large collections of the "Thor" from more northern waters during the earlier years 1905, 06 and 07 have also been placed at my disposal. Altogether, both in quantity and quality it is a unique collection of the postlarval stages of flat-fishes and Dr. Johs. Schmidt, the leader of the Danish Oceanographical Expeditions, is to be congratulated on its accumulation.

The determination of the postlarval flat-fishes, particularly from the Mediterranean, necessitated a more or less extensive investigation of the adult characters and this led, naturally, to the procuring of adult specimens. Some Mediterranean material was already in my possession from Banyuls-sur-mer, thanks to the liberality of the esteemed Director of the Laboratoire Arago, Professor Pruvot. A number of adult specimens were also brought home by Dr. Schmidt from his Mediterranean cruises and a few specimens have since been received, through Dr. Schmidt, from the Danish Consul General at Algiers, Dr. Nissen. Further, the Zoological Museum of Copenhagen possesses a good collection of Mediterranean flat-fishes, and this I have been able to examine through the generosity of Professor Jungersen and the friendly assistance of Dr. Ad. Jensen.

The examination of the Mediterranean specimens, however, opened up some important questions with regard to the identification of the northern species of flat-fish and led to my obtaining material from various quarters; Plymouth (Dr. Allen), Helder (Dr. Redeke), Kattegat (Dr. Johansen) and San Sebastian (Prof. Rioja). The material sent me from Plymouth was particularly good. Lastly, my friends Prof. Ehrenbaum of Hamburg and Dr. C. G. Joh. Petersen of Copenhagen have most kindly lent me some postlarval specimens of species already described by them.

Perhaps the principal result of the examination of all this mass of material is, that still more material is required; meantime, however, I venture to publish an account of some of the results already obtained.

Postlarval specimens of flat-fish have been taken in the Mediterranean by the "Thor" at 89 stations, 21 winter stations and 68 summer stations. The months in which investigations were made, number of stations in each month and number of pelagic specimens of flat-fish (including specimens just metamorphosed) are summarised in the following table.

		No. of stations	No. of pelagic flat-fish
December	1908	5	39
January	1909	9	15
February	—	7	12
June	1910	12	164
July	—	17	259
August	—	28	218
September	—	11	81
		89	788

In addition, postlarval flat-fish were taken at 7 stations in the Atlantic west and south-west of the Portuguese coast and also at 1 station in the Bay of Biscay. Chief interest centres naturally in the Mediterranean samples and it need only be mentioned here that *Sc. norvegicus* was taken at one of the Atlantic stations (85) and 2 *P. microcephalus* at another (79). These 8 stations are also included in the main tables, but it is of convenience to mention here what they were: Bay of Biscay St. 2, Novem. 1908; Atlantic Sts. 64, 65, February 1909, Sts. 79, 85, June 1910, Sts. 233, 145 and 248 in September 1910.

All other stations are taken as belonging to the Mediterranean region, though a few (62, 93, 94, 96, 229) lie just outside the Straits of Gibraltar.

The stations in the Mediteranean are distributed over the whole of this Sea, both in the western and eastern basins, from Gibraltar to the Sea of Marmora, and only smaller areas have been left untouched, as, the northern part of the Adriatic, southern part of the Sidra Sea and the eastern portion of the Levant. The results should give, therefore, a fairly good general picture of the flat-fish life of the Mediterranean.

The material has been collected almost entirely by the young-fish trawl, an apparatus invented by Dr. Petersen and described by Dr. Schmidt in Vol. I, p. 8. During the winter cruise of 1908—09 the young-fish trawl was used at 42 stations in the Mediterranean, but pelagic flat-fish were only taken at 21 of these. The total number of hours fishing with the young-fish trawl in the Mediterranean amounted to about 110 (winter) and as only 65 specimens were taken, this meant working about 2 hours to get one specimen. The great majority of the hauls, however, were quite blank, the number of successful hours being only 24. Of the 65 specimens 45 belonged to one species, *Bothus podas*, and the great majority of all the specimens (54) were taken near the surface from 0 down to about 40 meters (fishing with 65 meters wire out; see Vol. I, p. 13); a considerable number of hauls in 600 meters down to over 3000 obtained no specimens of flat-fish at all.

In the summer time, naturally, there was more profit on the work expended. The total number of hours fishing with the young-fish trawl was about 98 and the number of pelagic flat-fish amounted to 723; thus an average of between 7 and 8 per hour. The total number of stations investigated with the young-fish trawl was 96, but 28 of these were blank. The average catch per hour in the different months works out in round numbers as follows.

June	hours	fishing	ca.	16	no.	of	specimens	10	p.	hour
July	—	—	-	40	-	-	—	6	-	—
August....	—	—	-	32	-	-	—	7	-	—
September.	—	—	-	9	-	-	—	9	-	—

The average catch even in the summer time does not give the impression of abundance of flat-fish, but it has to be noted, that the majority of the stations were over deep water. The following summary groups the stations (winter and summer) according to depth.

0-100 meters	21	stations
100-500 —	19	—
500-1000 —	27	—
1000-2000 —	29	—
2000-3000 —	31	—
3000 + —	9	—

It thus appears, that most of the stations lay over deep water where we would not expect beforehand to find many flat-fish. As will be shown in more detail later, also, most of the specimens were taken at the stations in comparatively shallow water.

The hydrographical and topographical conditions in the Mediterranean have naturally a great deal to say in the distribution of the pelagic stages of the flat-fishes. According to Dr. J. N. NIELSEN's valuable report in Vol. I, the circulation of the upper layers, with which we are mainly concerned, may be briefly outlined as follows. On the southern side along the north coast of Africa there is the great oceanic current flowing horizontally eastwards from the Straits of Gibraltar to Egypt; in the northern, more indented and broken coast-line the circulation takes the form in general of a series of independent cyclonic movements in the separate basins, as the Aegean Sea, Ionian Sea and Tyrrhenian Sea. The general effect of the currents on the pelagic stages of flat-fishes would thus be, to carry them offshore. When we consider the depth contours, further, how the 200 m. line runs close to the coast everywhere except in the Adriatic and close to Tunis, and how the bottom slopes rapidly down to 1000 m. and more, we see at once, that the conditions for the existence and maintenance of a flat-fish life are very different in the Mediterranean from those we are acquainted with in more northern waters, except along the western seaboard and the Norwegian coast. The conditions will tend to develop two types of flat-fishes, those which have a very short pelagic life and those in which the pelagic life is very prolonged, since the natural destruction of the early, metamorphosed stages must be enormous. We do not believe, for example, that the metamorphosed stages of such shallow-water forms as *A. Grohmanni*, *A. Thori* and *A. laterna*, can live in depths of say 500 meters and more; and yet the "Thor" has taken the postlarval stages of these species out over 1000—3000 meters. Consequently, the flat-fishes which live along the narrow, coastal belt must either have a very short postlarval life, for example, *P. flesus*, *R. maximus*, *R. laevis*, most of the *Solea* and perhaps *L. Bosci* and *C. linguatula*, or if they have a prolonged postlarval life, as *Bothus* and most of the *Arnoglossus* species, they are specially adapted to the pelagic mode of life. In some cases, as will be shown, there is clear evidence of this prolonged, almost indefinitely prolonged postlarval life, for example in *Bothus;* even the young stages and adults may live pelagically. It has been known for some time also, that such species as *Arnoglossus*, in contradistinction to *Pleuronectes*, metamorphose pelagically. It is probable, therefore, that in this, the pelagic mode of life of the metamorphosing specimens, we have a special adaptation to the conditions in the Mediterranean and along the Atlantic seaboard.

With regard to the distribution of the pelagic stages of flat-fishes in the different layers of water, it will be seen from the main tables, that the great majority of the specimens were taken in the upper layers from 0 to 40 meters, even out over the greatest depths. There is, however, one striking exception which is worthy of special mention. At St. 122, namely, 73 specimens of *A. laterna* and *A. Thori* were taken at a depth of about 400 meters. Unfortunately, no hauls were made in the upper layers at this station, but it is fairly certain, that the specimens really came from the depth mentioned, the duration of the haul being 60 minutes. What the phenomenon may have been due to is not clear.

So far as I can see, my material shows no special indication of the peculiar hydrographical conditions in the Mediterranean. It is conceivable, in fact certain, that the great oceanic current which enters at the surface through the Straits of Gibraltar, may bring in a considerable number of postlarval flat-fishes

from the Atlantic, but so far as can be seen, it only brings in additional specimens to species which already spawn in the Mediterranean. On the other hand, the outgoing Mediterranean current in the deep layers conceivably carries out some pelagic specimens, but it is difficult to say in any given case, whether the specimens of a species, supposed to be Mediterranean, have really come from that Sea or have been spawned in the Atlantic. For example, *Bothus podas* occurs both in the Mediterranean and Atlantic, it is probably as much an Atlantic as a Mediterranean species; hence it is not remarkable to find postlarval specimens in Cadiz Bay. A more remarkable case is that of the so-called *Arnoglossus Grohmanni*. This was supposed to be preeminently a Mediterranean species and the few, isolated specimens, which have been taken in the southern British waters have been supposed to be chance wanderers from the Mediterranean. As a matter of fact, however, the so-called *A. Grohmanni* is certainly a not-uncommon inhabitant in the southern parts of the Bay of Biscay and certainly spawns there as also in the Channel (HOLT, 1889).

The species of flat-fish, which are restricted to the Mediterranean and immediately adjacent waters, are the following:

Lepidorhombus Bosci (Risso)
Arnoglossus Grohmanni (Bonap., non auctorum)
Citharus linguatula L.
Solea Kleini (Risso).
S. - nasuta (Pall.).
S. - monochir Bonap.
Symphurus lactea (Bonap.).
Symphurus ligulata (Cocco).

Of these, however, *L. Bosci* is supposed to occur in the Bay of Biscay, though it is probably confused there with *L. megastoma* (see later, p. 13) and *S. lactea* has been taken in the Bay of Biscay and at the Azores; *S. ligulata* also occurs in the Atlantic south of the Mediterranean.

A list of the species of flat-fish taken by the "Thor" in the Mediterranean (including the stations just outside the Straits of Gibraltar) may be given here along with the total number of postlarval or pelagic specimens of each.

	Number of specimens summer	winter
Arnoglossus Grohmanni (Bonap.)	27	
— *Thori* nov. nom. (= *A. Grohmanni* auct.)	299	3
— *laterna* sens. lat.	238	2
— *imperialis* (Raf. = *A. lophotes* G.)	7	4
— *Rüppeli* (Cocco)	7	5
Bothus podas (Delar.)	100	45
Solea vulgaris Quens.		4
— *variegata* (Don.)	1	
— *lutea* (Risso)	3	
— *Kleini* (Risso)	1	
— *lascaris* (Risso)	1	
— *nasuta* (Pallas)	3	
— *capellonis* Steind. (= *S. profundicola* Vaill.)	2	
Symphurus lactea (Bonap.)	34	2
(— ligulata (Cocco)	2)	
	723	65

It would appear from these samples, that the two *Arnoglossus* species, *A. Thori* and *A. laterna*, are the commonest flat-fishes in the Mediterranean. Both species occur mainly in shallow water, so that this conclusion is not affected by the fact, that the "Thor" fished mostly in open water over great depths. It will be shown, however, that the great majority of the specimens of these species came just from the few hauls near the coast. On the other hand, *Bothus podas*, the third in frequency, was taken mostly over great depths, very few being taken in the hauls near the coast. Hence the relative abundance of the two *Arnoglossus* species in the Mediterranean, by comparison with *B. podas*, must be many times greater than is shown by the above summary. This applies also to *A. Grohmanni* and the *Solea* species, which with few exceptions were only taken in the hauls made near the coast. There remain the two *Arnoglossus* species *A. imperialis* and *A. Rüppeli*, and *Symphurus*. The two former are known to be deep-water forms, at least in the postlarval stages. Further, as will be shown later, their postlarval life is very prolonged. Hence all things were in favour of the "Thor" obtaining a good number of specimens, if the species are at all abundant in the Mediterranean. This they do not seem to be, however: 12 specimens can hardly be said to make a species common. On the other hand, 36 postlarval specimens of *Symphurus lactea*, which is reputed to be rare (Moreau), must be considered a very good booty. The adults of this species live in comparatively shallow water and the postlarval specimens have been taken not far from the coasts, though frequently over very deep water. The 2 specimens of *S. ligulata* were not taken by the "Thor", but by the "Pangan" and "Florida" at the surface in the Ionian Sea over 3—4000 meters and in the Atlantic.

This rough survey, and it is obviously impossible to make a close, detailed comparison on the basis of this material, indicates, that *A. Thori* and *A. laterna* are by far the commonest species of flat-fish in the Mediterranean. *B. podas* may come next in frequency, but its prolonged postlarval life coupled with the fact, that the "Thor" fished mostly over deep water, have tended to heighten the relative frequency of this species. At the other extreme, we may conclude, that *A. imperialis* and *A. Rüppeli* are rare. But very little can be said about the frequency of the remaining species, except perhaps that *Symphurus lactea* is much commoner than was thought and that the true *A. Grohmanni* of Bonaparte is not uncommon. The numbers for the species of *Solea* do not seem representative.

A curious feature in these samples from the Mediterranean is, that some species of flat-fish are not represented at all. However this may be explained, and of course some explanation may be attempted, time of year of the cruises, fishing mostly over deep water etc., it is yet surprising, that not a single specimen of *R. maximus*, *R. laevis*, *L. Bosci* or *C. linguatula*, not to mention *P. flesus*, has been taken there. These are all among the common species of flat-fishes in the Mediterranean.

On the other hand, their absence is to a great extent counterbalanced by the presence of some interesting forms, either unknown previously or imperfectly, even erroneously described. Among the prizes may be mentioned: complete series of *Symphurus lactea* (Bonap.), a remarkable form with a remarkable metamorphosis, of *Bothus podas* (Delar.), the mysterious *Peloria* of earlier Italian authors, and of *Arnoglossus Rüppeli* (Cocco) the *Bascanius* of Schiödte and *Charybdia* of Facciolà; further, a few specimens of *Symphurus ligulata* (Cocco), the *Bibronia* of Cocco, confused with *Trachypterus* by Emery, and of various species of *Solea*. Among the surprises we find, that the common *Arnoglossus* form, which has always been called *A. Grohmanni* (Bonap.), is not really Bonaparte's *Grohmanni*; this is also represented in the collections; further, that the disputed *A. lophotes* Gthr. was adequately described more than 100 years ago; further, that *A. laterna* is a composite species, containing a number of varieties, if not distinct species; and also, that even the common sole, *S. vulgaris*, contains two species. These and various other things will be explained in the following pages.

Inasmuch as the material does not represent the whole flat-fish fauna of the Mediterranean, its systematic arrangement and treatment must be somewhat imperfect. The nomenclature and classification,

for example, require more exhaustive treatment and careful scrutiny than the scope of this work permits, especially since the American authors made their cursory inroad into European ichthyology. As it is just as important to give a fish its correct name as to describe it, however, I have taken some trouble to find out the proper designation of the species dealt with here. On this ground the remainder of the Introduction will not be found superfluous.

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b. RHOMBUS, a question of nomenclature.

In ichthyological literature of recent years the same species appear under the different names of *Pleuronectes, Rhombus, Psetta* and *Bothus.* Not many years ago, one never thought of calling these species anything but *Rhombus.* A few years hence and some more names may be added to the list. One at least is waiting its opportunity.

The turbot and brill have been known from time immemorial as *Rhombus,* certainly from the time of the Romans (1st century A. D.).[1] Two hundred years before LINNÉ, *Rhombus* appeared definitely in scientific literature (RONDELET). In the century preceding LINNÉ, WILLUGHBY and JOHNSTON had made considerable progress with the classification of the flat-fishes, as we know it at the present day, subdividing the known forms into groups and giving each form a definite, double name. KLEIN, a contemporary of ARTEDI and LINNÉ, divided the flat-fishes into 3 genera, giving each a definite generic name. From KLEIN onwards to 1817, a period of 70 years, progress in the systematic classification of the flat-fishes was retrograde. In 1817 CUVIER began where KLEIN had left off and CUVIER'S classification has formed the basis of that of the present day. During the next period of 70 years progress was rapid and fairly consistent, through RISSO (1826), BONAPARTE (1832—46), BLEEKER (1858—62), GÜNTHER (1862) to GILL (1873). During this period I have only been able to find three authors who have used any other name but *Rhombus* for the turbot and brill; over 90% of the authors have used *Rhombus,* successively as generic and later as subfamily name *(Rhombinae).* Since 1882 a desire for change has made itself manifest, and as changes are easy each decennium since then has seen a "new" name. With the end of another decennium at hand we may prepare ourselves to welcome a new-comer from the systematists and, curiously enough, if the letter and not the spirit of the rule of priority is adhered to, the new-comer may be the right guess at last.[2]

It seems to me, that a name with such a long and clean record as *Rhombus* has, is worthy to be maintained, and the best way of supporting it, is to show the unworthiness of the substitutes. Briefly put, I hope to show, that *Pleuronectes* is impossible, *Psetta* merely an afterthought and *Bothus* nothing but a hybrid of no standing save as the name for a genus and subfamily under the *Rhombidae.* Whatever its position may be relative to names used in other groups, a question that will be discussed later, it is certain that *Rhombus,* among the flat-fishes, has post-Linnean priority and authority as well as the tradition of centuries to support it against these three substitutes.

The trouble dates from ARTEDI and LINNÉ, the great systematists who knew no law of priority and reduced all the flat-fishes, whose names they could find, to one and the same dead-level — *Pleuronectes.* In the dark period which followed, writers on the flat-fishes (BRÜNNICHE, PENNANT, O. F. MÜLLER, BLOCH, WALBAUM etc.) still made use tacitly of the subdivisions of KLEIN, but refrained from giving them names,

[1] The reference in Juvenal's Satires, "spatium admirabile Rhombi", from the Adriatic, kept in a tank for the delectation of the Emperor Domitian, is assuredly to the turbot or brill, most probably the former. Ovid and Pliny refer to the same fish. "Rhombo" has been the common name for the turbot at Venice for centuries.

[2] I refer here to the "*Scophthalmus*" of Rafinesque-Schmalz. It is possible, that some one may put this name forward, but I think, that the reasons given in the text for ignoring the classification of Rafinesque should prevent such an attempt being made.

presumably out of respect for the great systematists. *Rhombus* was quite dormant and one author (Lacépède 1798—1803) even gave this name on temporary loan to a subgenus of the Scombridae. As over 30 species of flat-fish were known by that time, it must be admitted that respect for Linné was carried to an extreme length. By way of counterbalance, perhaps, when the uniformity of the Linnean classification was once broken (Quensel 1806) we find, that the process of subdivision was carried to the other extreme (Rafinesque-Schmaltz 1810). Cuvier and subsequent systematists until 1882 ignored both extremes.

When the necessity for expansion arose and *Pleuronectes* had to be regarded as the designation of a higher order than genus, two logical courses were open, either of which would be consistent with the principle underlying the rule of priority. Either the name *Pleuronectes* should have become the title of the subfamily, family etc. and should not have been used at all as generic name, or, if used as generic name, it should have been applied to the first natural group of species in Linné's system. The term *Pleuronectes* applies to all flat-fishes alike and for this reason one would favour the first course, which was followed as a matter of fact by Cuvier (1817; with the four main groups: *Platessa, Hippoglossus, Rhombus* and *Solea*). Use and wont, however, have decided in favour of the second course, and as the American authors (1899) have now come into line with the great majority of the European, we may hope that this point is finally settled.

In the work last-cited of Jordan and Evermann we find the whole Turbot group called *Psettinae*, the turbot itself *Psetta maxima*, but the brill *Bothus rhombus*. *Psetta* was suggested by Swainson in 1838—39 and taken up by Bonaparte (1846), but no other author has used it. The assumption that the name has the authority of Aristotle is also very uncertain; if a flat-fish at all, the *Psetta* of the latter was more probably the "*Rhombus aculeatus*" of the 17th and 18th centuries, that is, the sinistral *P. flesus*. It seems a little curious that Prof. Jordan, who was the first to introduce *Bothus*, to replace it later by *Pleuronectes*, should now suggest *Psetta*. It is possible that he has seen very early that *Bothus* was untenable, then later that *Pleuronectes* was unnatural, so finally and somewhat hesitatingly he has put forward *Psetta* as an afterthought. The changes rung by Prof. Jordan on these names for the Turbot group, constitute a good argument for their rejection.

The greatest rival to *Rhombus* has been *Bothus*. The genus *Bothus* was formed by Rafinesque-Schmaltz in 1810 for 3 species, none of which have up to the present been identified with certainty. The genus was tacitly ignored by Rafinesque's own countrymen (Risso, Bonaparte, Canestrini) and by all ichthyologists until its resurrection by Jordan and Gilbert in 1882. Since that date it has gradually replaced *Rhombus* even in the literature of European systematists (Collett, Lilljeborg, Smitt, Tate Regan). Various guesses have from time to time been made as to what the "species" may have been and among these we find, that Bonaparte (1846) included the first of them (*Bothus rumolo*) as a synonym under *Psetta* (*Rhombus*) *laevis*. This may account for its resurrection, but the inclusion of the name in that work was most probably a *lapsus calami*. In 1832, at any rate, Bonaparte had redefined *Bothus* and it seems to me more than a mere coincidence, that he should have applied the name then to a species, which, I have come to believe, was undoubtedly the *Bothus rumolo* of Rafinesque.

As the papers of Rafinesque are not very accessible, I may quote his descriptions and diagnoses in extenso. In his "Opuscolo" published early in 1810 we find the following definition of *Bothus*.

"G. *Bothus*. — I due occhi alle sinistra, ale dorsale ed anale distinte e separate della caudale, una sola ala giugulare."

A single ventral would at once remove the genus from relationship with the turbot and brill, and if we add to this, that the dorsal and anal fins were separated from the caudal, there is no group of flat-fishes in which we can place it. Rafinesque is not only the author, however, who found only one ventral in certain species of flat-fishes[1], but no author has ever made this mistake with regard to *R. laevis* — not even Rafinesque!

[1] cf. Cocco (1844); Facciolà (1885).

"Oss. Porzione delle specie del genere *Pleuronectes* degli autori compongono questo nuovo mio genere, il quale si dovrebbe chiamare *Rhombus* dalla principale delle specie che contiene, se Lacépède non avesse gia attribuito tal nome ad un altro suo genere, il nome di Bothus e pero un di quelli dati da Aristotile ai Pesci di quest' ordine."

An interesting point arises from the first part of this statement. If LACÉDÈPE's "*Rhombus*" is not recognized and *Bothus* will not bear the meaning given it by the American authors, this statement gives the name *Rhombus* to the turbot and brill. In the last part RAFINESQUE suggests that the name *Bothus* may be found in ARISTOTLE. SMITT (1892) remarks on this, that *Bothus* sounds more like a cross between the northern "bott" or "butt" and the Greek *βαθή*.

It is not necessary to reproduce the full account given by RAFINESQUE of his three species. The last, *Bothus Imperialis*, is certainly an *Arnoglossus*, as I shall show later. It is the only one of the three which is absolutely certain, from the description. The second, *Bothus Tappa*, reasoning by exclusion, is also an *Arnoglossus* and BONAPARTE placed it with a query as a synonym to his *Pleuronectes* (*Arnoglossus*) *Grohmanni*. RAFINESQUE's note on this species is of importance. "Questa specie e ancora piu piccola e piu stretta della precedente (*Bothus Rumolo*), ha la bocca piu grande, con i denti piu apparenti — — —." If an *Arnoglossus* species had a larger mouth with teeth more apparent than *Bothus Rumolo*, our guess at what the latter may have been, is narrowed down to two species, neither of them *R. lævis*. But RAFINESQUE's own words are also quite explicit on this point.

"*Bothus Rumolo.* — La lunghezza del corpo piu grande dell' altezza, ala dorsale principiando sopra l'occhio, linea laterale curva alla base, lato sinistro liscio fosco senza macchie, il dritto bianchiccio, coda rotondata.

Oss. Il suo nome specifico e parimente il suo nome volgare, differisce dal *B. Rhombus* (*Pleuronectes Rhombus* Linn.) nell' essere piu piccolo, un poco piu stretto e lungo, nel non avere il lato sinistro macchiato &c."

If there is anything clear about this description, it is that *B. rumolo* was not *R. lævis*. We are able to recognize the species from the note on *Bothus Tappa*, quoted above, along with the words "lato sinistro liscio fosco senza macchie." The description agrees with some exceptional specimens of *B. podas* Bonaparte (= *Platophrys podas* Swainson and later authors), which I have in my possession from the Mediterranean. In these the ordinary spotted marking of this species is not apparent and the eyed side is of a light brownish colour. It is of some interest to note here, that RAFINESQUE added later (1817) a fourth species to this genus, namely, *Bothus diaphanus*. This has long been supposed to have been the young of *B. podas*.

In his second work, "Indice d'Ittiologia Siciliana", also published in 1810 but a little later than the "opuscolo", RAFINESQUE continues with the classification of the flat-fishes. Here the whole group is called Pleurostami, with the two subdivisions Achirini and Pleronetti. The latter is further subdivided into 3 genera, in the second of which we find the turbot and brill (with two ventrals!) and in the third the *Bothus* species discussed above. I do not think it would serve any useful purpose to discuss or revive this system of RAFINESQUE; it is not a classification but merely a miscellany. His own countrymen have been more charitable to RAFINESQUE than the American authors. To adapt a well-developed, modern classification to the obscure and imperfect names and diagnoses of RAFINESQUE, is like pouring new wine into old bottles — the result is equally disastrous in both cases.

We may turn now to what is perhaps the most important question: the status of *Rhombus*. Though the *Bothus* of Rafinesque was a derelict and his classification obsolete and unadaptable, we may yet take note of his expressed thought, that *Rhombus* belonged to the Turbot and Brill, had not LACÉPÈDE given the name to another genus of fishes.

This is in agreement with what has been said above, namely, that during the whole period from LINNÉ to CUVIER, *Rhombus* was merely behind a cloud. All authors of the time, including LINNÉ himself,

tacitly made use of this subdivision of KLEIN and gave *Rhombus*, and no other name, as a synonym to the turbot and brill. Further, it has to be remembered that KLEIN (1740—1746) was a contemporary of Linné (1735—1757 (66)) and has suffered from that fact.[1] With *Rhombus* always on the spot, as it were, there is complete continuity from the earliest times until a very few years ago.

It is of interest to note also, how time brings its own revenge. The authors who have hunted *Rhombus* from the flat-fishes, have by their own action bound themselves to the tread-mill of change. Three times within 30 years they have altered the name of the turbot group and after building a fine house for *Rhombus* among the Scombridae, they have been obliged to pull it down again — in a foot-note (JORDAN and EVERMANN, 1899). LACÉPÈDE, it appears, was not the only one who made improper use of *Rhombus* during the dark period; the American ichthyologists have found that this name was applied to a mollusc in 1797, a year or two before LACÉPÈDE made use of it. Thus, in accordance with their reading of the law of priority, the American authors decree, that *Rhombus* must vanish altogether from the fishes. Reference to SCUDDER's "Nomenclator" shows, however, that we cannot stop there. Previous to 1797, *Rhombus* was used no fewer than twice for different species of Mollusca, and after 1797 it was used twice again for various species within the same group.

On referring to HERMANNSEN (1847—49) we find that 4 of the above references among the Mollusca have long been obsolete and the fifth (1776), according to friendly information received from Dr. ADOLF JENSEN of Copenhagen Museum, is on its travels somewhere and cannot at present be found. The net result of the whole procedure would thus be, that *Rhombus* is about to depart from the Animal Kingdom — perhaps "reculer pour mieux sauter"!

If we reject this *reductio ad absurdum* and ignore also the usurper *Bothus*, save in the sense to be explained hereafter, we may reinstate *Rhombus* as the head of the "tapeworm" which it adorned in modern, scientific literature for more than 60 years.

c. Classification of the RHOMBIDÆ

A considerable number of questions still await their solution with regard to the **Rhombidae,** both in the nomenclature and the classification, but if we confine ourselves to the European species, the difficulties are not so great. In an earlier paper (1900) I separated *Citharus* from the turbot subfamily and pointed out, that *Arnoglossus* and "*Rhomboidicthys*" were also well-marked off by certain important characters from the other members of the subfamily. In his more recent revision of the classification, TATE REGAN (1910) has carried the process of subdivision still further and definitely grouped together *Arnoglossus* and "*Rhomboidichthys*" in a separate subfamily. By this process we automatically raise *Rhombus* to the status of a family: **Rhombidæ,** with 3 subfamilies, all represented in European waters, the first by the single species *Citharus*, the second by 5 or 6 species of *Arnoglossus* and one of "*Rhomboidichthys*", the third also by 7 species, grouped variously according to the views of authors into 2, 3 or more genera. To the first subfamily TATE REGAN gives the name *Paralichthinae* from the principal American genus, to the second *Platophrinae* and to the third *Bothinae*. The names of the last two require revision.

"*Rhomboidichthys*", which under the name of *Platophrys* is the type of TATE REGAN's second subfamily, was the name used by BLEEKER (1856) for a genus, which has one representative in the Mediterranean, the *Pleuronectes podas* of DELAROCHE (1809). Later (1862), BLEEKER replaced the name *Rhomboi-*

[1] The attitude of LINNÉ to his contemporaries and of his contemporaries to LINNÉ is revealed perhaps in a little story told by O. F. MÜLLER. LINNÉ would not admit that certain worms had a head; tapeworms he took to be sort of hybrid animal-plants. When one of his former pupils ventured to suggest, that a tapeworm really had a head, LINNÉ replied in the true Johnsonian manner: It has no head, and shall not have any ("Den har intet Hoved og skal intet have").

It does not spoil the story to give MÜLLER's reply. He would not discuss the philosophy of the question with his revered master, but the had thought, that "a segment at the end of the body, distinct from other segments, provided with an opening, with teeth or sucking apparatus, and which drags the other segments after it, might be permitted to be called a head" (1781).

dichthys by *Platophrys*, which had been suggested by SWAINSON (1838—39). GÜNTHER, in the meantime, had taken up *Rhomboidichthys* and we find this name still in use in the Italian literature. The American authors took up *Platophrys*, however, and this name has been adopted by most recent writers (COLLETT, LILLJEBORG, SMITT, TATE REGAN). There is still a third name in the list, *Bothus*, which was given to the genus by BONAPARTE, was used later by STEINDACHNER (1868) and has since been retained by French writers (MOREAU). On a smaller scale we thus have the same confusion as in the case of *Rhombus*.

Rhomboidichthys is certainly antedated by the other two names, but it seems to me equally certain, that *Platophrys* was preceded by *Bothus*. It is in part a question, when the respective works of BONAPARTE and SWAINSON were published. The date of the latter is admittedly 1838—39, but the publication of the former was spread over the years 1832—41. The authors who have taken up *Platophrys* have apparently taken the last year, 1841, as the year of publication of BONAPARTE's work and have thus given *Platophrys* the preference over *Bothus*. I do not think that this is right. The diagnosis and description of *Bothus* were issued in BONAPARTE's 4th "fasciculo" and on referring to the Plate, which gives the name and figure of the species, we find that it bears the date 1832. This would be sufficient to give *Bothus* the preference, but we have also the additional reasons, as mentioned previously, that the *Bothus rumolo* (1810) and *Bothus diaphanus* (1814) of RAFINESQUE belonged to this same species.

Arnoglossus and *Bothus* have been united by SMITT (1892) into one genus, but this does not seem justifiable. There are some 10 species in each genus and the differences between the two genera, in form, structure of the head, scaly covering and development, are very well-marked.

The third subfamily, which should now bear the name *Rhombinae*, contains an ill-assorted collection of species, which have not been easy to classify and have consequently received a variety of names. The turbot and brill form one pair, in a class by themselves and distinguished from the other species by having small, cycloid scales or none at all. The 5 remaining species are grouped together and distinguished from *Rhombus* by a very remarkable character, which by some authors (STEENSTRUP, PETERSEN) has been taken as a generic character. This is the perforation above the urohyal of the septum between the branchial cavities. If we add another peculiarity, however, namely, the absence of an air-bladder in the postlarval stages, we see, that this group of 5 species may be contrasted not only with *Rhombus* as a genus, but also with the *Bothinae* as a subfamily and possibly also with a still wider group. In other words, these characters are exceptional and of more than generic importance. On the other hand, if we take any of the minor characters, which have hitherto served as generic characters, presence or absence of vomerine teeth, scales, fins, pyloric caecae, we find that the 5 species in question arrange themselves into 2 or more genera, each as good in its way as the genus *Rhombus*. It seems to me justifiable, therefore, to regard this group as something more than a genus, let us say a supergenus, and the two characters mentioned above as exceptional, with a significance we at present have no means of understanding[1].

Whichever way we arrange these 5 species, there is always an odd one out. Two species only hold together, namely, *Lepidorhombus megastoma*[2] and *Lepidorhombus Bosci*, which have sometimes been

[1] For the different ways in which this remarkable group has been regarded and classified, reference may be made to the works of STEENSTRUP (1865), who was the first to give an accurate and full account of the distinguishing characters and who united all 5 species into one genus "*Zeugopterus*", COLLETT (1874—84) who distinguished 3 genera with different names at different times and SMITT (1892) who also distinguished betweeu 3 genera but arranged and named them differently. Dr. PETERSEN (1906, 1909) has recently adopted STEENSTRUP's classification, on the strength of the perforated gill-septum, but, as shown above, this is more than a generic character and if we are to unite all the 5 species under one genus, the name *Scophthalmus* (BONAPARTE 1832) has precedence of *Zeugopterus* (GOTTSCHE 1835). Besides, *Zeugopterus* in its application and as used by GOTTSCHE refers only to one species.

[2] Following the American authors (1889) and SMITT (1892) I have earlier (1900) called this species *Lepidorhombus whiff*, but further study has shown me that this is a mistake. The authors mentioned give WALBAUM and PENNANT as their authorities, but on referring to the works of the latter, we find that neither of these authors knew anything about the species and merely based their imperfect and erroneous description on an earlier figure by JAGO. The first to give a definite recognizable description of the species in question was DONOVAN (1802) and he called it *megastoma*, the name by which it has been known in the European literature for practically 100 years.

taken as one species only. These are most readily distinguished from the other 3 species by their form and their scales. It seems to me that we obtain the key to the subdivision of the species in the last character, which is also a generic character for *Rhombus* and also, in a somewhat similar way, a generic character distinguishing *Arnoglossus* and *Bothus*. We then obtain 3 genera under the subfamily *Rhombinae* namely, *Rhombus*, with small, smooth scales or none; *Lepidorhombus*, with scales of moderate size, ciliated on the eyed side only and somewhat deciduous; *Scophthalmus*, with moderate or small scales, very adherent and ciliated on both sides of the body.

None of the other characters, which have been taken as generic characters, are opposed to this arrangement, though naturally their value is altered. The vomerine teeth were used by GÜNTHER (1862) as a very important character in the separation of the *Rhombidae*, and BLEEKER (1862) attached very great importance to the teeth in general. But these are among the irregular characters, which may or may not be of use in classification, according to the habits of the species. Thus, as pointed out by STEENSTRUP (1865), one species of *Belone* has vomerine teeth, another not, and in the present group vomerine teeth are present in *Lepidorhombus* and *Zeugopterus* (adult stages), whilst they are absent in *Sc. unimaculatus* and doubtfully present (present or absent) in *Sc. norvegicus*. In *Zeugopterus* again, there are no pyloric caecae (STEENSTRUP), whilst the other species, like *Rhombus*, have 2. Further, the ventral and anal fins in *Zeugopterus* become joined after the adult form has been assumed. It is evident from these irregular characters, that *Zeugopterus punctatus* has specialised away from the other Topknots and thus merits the rank of a separate subgenus, but no more.

The affinities and divergences of the 5 species are also displayed by other characters. In the postlarval stages, as PETERSEN has shown (1909), *Lepidorhombus megastoma*, *Sc. unimaculatus* and *Z. punctatus* are remarkable for the presence of a small number of large, isolated spines on the otocystic region. By contrast, *Rhombus* has a large number of small spines on the preoperculum, whilst *Sc. norvegicus* and the so-called *Lepidorhombus Bosci*[1] have similar small spines on the lower jaw, preoperculum and pectoral arch. The differences in the skull are perhaps of even greater importance. In all species of the *Rhombinae* the dorsal fin grows forwards on the snout after the migrating eye has come round to its final position. In *Scophthalmus norvegicus* the interspinous bones supporting this front part of the fin are based almost directly on the skull, on a low, flat ridge of bone runing forward from the supraoccipital to the frontal of the right side, to aid in forming the so-called pseudomesial ridge. In the turbot and brill *(R. maximus* and *lævis)* the ridge is very prominent and in *Z. punctatus* and *Sc. unimaculatus* it has developed into a high and narrow crest. In *Lepidorhombus* the crest is still higher and perforated at its base by a large foramen (see text-figure 1).

Figure 1.

Lateral view of skulls of a. *Lepidorhombus megastoma* and *Bosci* × 1 ½; b. *Sc. unimaculatus* and *Z. punctatus* × 2; c. *Sc. norvegicus* × 2 ½.

Summing up, this small group of 5 species shows a great diversity of well-marked characters, each of which if supported by a number of species, might well be taken as characters of a generic or even higher order. Some are, to my mind, primitive characters (e. g. those

[1] It is very doubtful if the species called *L. Bosci* (*Z. Boscii*) by PETERSEN is the true *L. Bosci* of the Mediterranean. PETERSEN's postlarval specimens came from W. and S. W. of Scotland and Ireland. They have a higher number of vertebrae and fin-rays than the Mediterranean *L. Bosci*, and it would seem, therefore, that there are 3 species of *Lepidorhombus* in European waters; namely, a northern form (*borealis*) called *megastoma* by PETERSEN; secondly, the true *megastoma* of DONOVAN from the Channel and west coasts, the postlarval stages of which are distinct from those of the more northern form; and lastly, the Mediterranean *L. Bosci* of RISSO. The characters of these forms require further investigation.

of *Sc. norvegicus*), others are undoubtedly the result of special adaptations in habits (e. g. *Z. punctatus*).

In accordance with the above, the European species and genera of the family **Rhombidae** may be classified as follows.

Paralichthinae: both ventral fins lying behind the clavicles; hæmal processes meeting to form a closed arch on the 4 posterior abdominal vertebrae; only 2 pyloric cæcae; lateral line distinct on right side of body.

Only one species in European waters: *Citharus linguatula* L.

D. 64—48; A. 44—46; Vert. 10 + 26 = 36.

Bothinae: only the ventral fin of the blind side behind the clavicles, that of the eyed side continued forward to the lower prong of the urohyal; hæmal processes meeting to form a closed arch on the 4 posterior abdominal vertebrae; 4 pyloric cæcae; no lateral line on right side of body.

Two genera of this subfamily are represented in European waters, namely, Arnoglossus and Bothus.

Genus Arnoglossus Bl.: height of the body not more than one-third of the total length; eyes close together, separated by a narrow, convex ridge; mesopterygoid of blind side present; scales of moderate size, lightly ciliated, deciduous.

At least 5 species in European waters.

1. *A. Grohmanni* (Bonap., non auctorum).

   D. 73—79 (80); A. 51—57; Vert. 10 + 23—24 = 33—34.

2. *A. Thori* nov. nom. (= *A. Grohmanni* auct.).

   D. (84) 86—89 (92); A. (63) 64—67 (69); Vert. 10 + (27) 28—29 (30) = (37) 38—39 (40).

3. *A. laterna* Will.

   D. 84—98; A. 63—75; Vert. 10 + (27—) 28—31 (32) = (37) 38—41 (42).

4. *A. imperialis* (Raf. = *A. lophotes* Gthr.).

   D. (94) 96—101 (105); A. (74) 76—79 (82); Vert. 10 + (32) 33 (—35) = 43 (42—45).

5. *A. Rüppeli* (Cocco).

   D. 110—116 (118 ?); A. 86—92; Vert. 10 + (33) 34 (35) = (43) 44 (45).

Genus Bothus: Height of body about one-half the total length; eyes wide apart (more so in males than females), separated by a concave space; mesopterygoid of blind side wanting; scales small, very adherent and strongly ciliated.

One species in European waters.

Bothus podas (Delaroche).

D. (85) 88—91 (94); A. (63) 65—68 (70); Vert. 10 + (28) 29 (30) = (38) 39 (40).

Rhombinae: both ventral fins continued forward in front of the clavicles to the urohyal; hæmal processes of the posterior, abdominal vertebrae open, not forming a closed arch; only 2 pyloric cæcae or none; lateral line distinct on right side of body.

A. Supergenus: branchial septum entire; postlarval stages with air-bladder (characters common to subfamily **Bothinae** also).

Genus Rhombus: Scales smooth, small or none; dorsal and anal fins not continued on to blind side of caudal peduncle;

Two species.

1. *Rhombus maximus* Will.: No scales, but tubercles.

   D. 57—64; A. 42—47; Vert. 12 + 18—19 = 30—31.

2. *R. laevis* Rond.: Small scales, not ciliated.

   D. 73—80; A. 54—61; Vert. 12 + 23—24 = 35—36.

B. Supergenus: branchial septum perforated between lower pharyngeals and urohyal; postlarval stages without air-bladder.

Genus Lepidorhombus Gthr.: Scales of moderate size, ciliated on the eyed side only and somewhat deciduous; dorsal and anal fins continued on to under side of caudal peduncle; Two species.[1]

1. *Lepidorhombus megastoma* (Don.).
   D. 85—91; A. 67—75; Vert. 10 + 31, 32 = 41, 42.
2. *Lepidorhombus Bosci* (Risso).
   D. 78—82; A. 62—67; Vert. 10 + 29—32 = 39—42.

Genus Scopthalmus[2]: Scales of moderate size or small, ciliated on both sides of the body and very adherent; dorsal and anal fins continued on to under side of caudal peduncle;

Subgenus Scophthalmus: Scales of moderate size or small; ventral and anal fins not united; two pyloric cæcae.
2 species.

1. *Sc. norvegicus* (Gthr.): scales of moderate size.
   D. 74—83; A. 63—68; Vert. 9 + 25—26 = 34—35.
2. *Sc. unimaculatus* Bnp.: scales small.
   D. 70—80; A. 61—68; Vert. 9 + 26 = 35.

Subgenus Zeugopterus: scales small; ventral and anal fins united in adult form; no pyloric cæcae.

Zeugopterus punctatus (Bloch).
D. 87—101; A. 67—75; Vert. 9 + 27, 28 = 36—37.

[1] See footnote pag. 13.
[2] Bonaparte 1832.

Record of the hauls of postlarval flat-fishes made by

a. W

(The numbers give the length of each

Length of wire out meters	Locality	Biscay	Ionian Sea; 14—15 Adriatic, 20—21 S. of Messina Straits						
	Station	2	10	11	13	14	15	20	
	Position N.	48°44′	37°21′	36°57′	39°43′	41°24′	40°04′	37°48′	3
	Position E.	4°55′W.	16°45′ E.	18°16′	17°30′	17°45′	19°06′	15°49′	1
	Depth in meters	112	>2100	>3700	>1200	1125	1000	>1300	
	Date	28-XI-08	15-XII-08	16-XII-08	19-XII-08	21-XII-08	22-XII-08	5-I-09	5
10—25	*Bothus podas* (Delar.)	..	12.5,14,17.5,18,18	13 from 10—22	19	..	21	20	
	Arnoglossus Thori nov. nom.	..	..	..	.	..	25.5	..	
	— *laterna*, form B.	..	..	..	..	..	..	..	
	— *imperialis* (Raf.)	..	18	..	..	..	..	..	
	Solea vulgaris Quens.	..	..	..	..	..	..	..	
65	*Bothus podas* (Delar.)	..	12, 14, 18, 19	15, 17, 19.5, 24	18	22, 32	..	..	
	Arnoglossus imperialis (Raf.)	7.5	..	..	..	..	..	..	
	— *Rüppeli* (Cocco)	..	15, 22	..	..	..	..	..	
	Solea vulgaris Quens.	..	..	..	..	..	..	..	
	Symphurus lactea (Bonap.)	..	..	..	20	..	..	..	
150—300[1]	*Bothus podas* (Delar.)	..	..	24	..	..	..	..	
	Arnoglossus Thori nov. nom.	..	..	18.5	..	..	..	..	
	— *laterna*, form B.	..	.	..	..	×	..	..	
	— *imperialis* (Raf.)	..	..	..	..	..	..	..	
	— *Rüppeli* (Cocco)	..	..	41	..	..	..	..	
	Symphurus lactea (Bonap.)	..	..	..	..	..	..	..	

[1] In addition, 15 hauls were made with varying length of wire from 600 to over 3000 meters, but without yielding any flat-fish.

b. Sur

(The size of the specimens is

Length of wire out meters	Locality	Atlantic; 85 off Portugal, 93, 94, 96 near Straits of Gibraltar								Alboran Sea; 98 in Stra							
	Station	85[1]		93		94		96		98		104		105		1	
	Position N.	38°22′		36°17′		36°06′		35°48′		35°57′		36°37′		36°43′		36	
	Position W.	9°28′		6°17′		6°02′		5°58′		5°35′		2°04′		2°08′		2	
	Depth in meters	>700		40		65		190		775		250		20		1	
	Date	17-VI-10		22-VI-10		23-VI-10		23-VI-10		23-VI-10		24-VI-10		24-VI-10		25-VI	
	Species	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	S
0—50	*A. Thori* nov. nom.	.	..	.	..	.	..	.	..	.	..	.	..	4	3<10, 11	.	
	A. laterna, form A.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	
	- — — B.	8	5<12, 13, 15, 24	2	6, 7.5	.	..	.	..	.	..	.	..	.	..	.	
	A. imperialis (Raf.)	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	
	A. Rüppeli (Cocco)	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	
	?*Solea Kleini* (Risso)	.	..	1	7	.	..	.	..	.	..	.	..	.	..	.	
	Symphurus lactea (Bonap.)	.	..	.	..	.	..	.	.	.	..	.	..	.	..	.	
65	*A. Thori* nov. nom.	.	..	.	..	.	..	.	..	.	..	78	5-14.5	.	..	5	4-
	A. laterna, form A.	.	..	.	..	.	..	.	..	.	..	4	< 10	.	..	.	
	- — — B.	.	..	.	..	3	6, 8, 9	5	10, 10, 11, 17, 24	2	10, 12	1	6	.	..	2	7
	A. imperialis (Raf.)	.	..	.	..	.	..	.	..	.	..	.	..	.	..	1	
	?*Solea Capellonis* Steind.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	
	S. lutea (Risso)	.	..	.	..	.	..	.	..	.	..	1	6.2	.	..	.	
	?*S. lascaris* (Risso)	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	
	?*S. nasuta* (Pall.)	.	..	.	..	.	..	.	..	.	..	2	5, 8.5	.	..	1	

[1] In addition, 2 specimens of *P. microcephalus*, 8 and 15 mm in length, were taken at St. 79, 17°30′ N., 6°43′ W., Bay of Biscay, and 1 specimen of *Sc. norvegicus*.

...or" in the Mediterranean and adjacent waters, 1908—10.

..., 1908—09.

... in mm. A × indicates empty hauls).

	Tyrrhenian Sea							North coast of Africa from Tunis—Sardinia to Morocco					Atlantic adjacent to Straits of Gibraltar		
	26	27	30	31	33	38	39	43	46	47	50	52	62	64	65
	40°40′	40°58′	41°15′	41°44′	43°03′	40°45′	39°11′	38°14′	37°17′	36°55′	37°02′	36°13′	35°45′	36°32′	35°53′
	13°59′	13°49′	11°55′	10°52′	9°35′	9°50′	10°02′	8°42′	6°00′	3°55′	1°17′	1°28′W.	5°59′W.	6°26′W.	7°26′W.
	530	90	>1800	1420	150	105	1750	>2000	1930	>2000	>2000	>2000	58	40	1300
	19-I-09	19-I-09	21-I-09	22-I-09	22-I-09	31-I-09	1-II-09	3-II-09	7-II-09	10-II-09	17-II-09	18-II-09	21-II-09	22-II-09	22-II-09
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	×	×	..	..	..	..	×	..	..	..	..	..	13.5	7.5	..
	..	..	..	..	..	8	..	..	..	..	..	..	..	..	..
	..	..	..	..	26	21, 25	32	22	..	26	26	..	..	..	..
	..	..	29.5	..	..	..	..	..	..	..	13	..	..	..	..
	×	×	..	×	..	..	..	..	18	..	..	..	..	×	×
	..	..	..	..	..	7, 7.5, 8.5	..	..	..	..	..	..	..	..	
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	.	..	..	29	..	..	..	..	..	24	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	.	51	×	..	..	×	×	..	×	..	×	8	..	..	×
	..	..	..	..	..	..	..	..	..	6.5, 7	..	..	..	..	..
	41	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	27	..	..	..	..	..	..	..	..	..	..	..	..	..

...1910.

... A × indicates empty hauls).

			Off Algiers		Alboran Sea; Oran to Gibraltar										Atlantic—Channel; 229 north of Straits of Gibraltar, 248 Channel							
	108		112		221		223		224		225		227		228		229		233		245		248	
	36°03′		36°56′		35°44′		36°13′		36°33′		36°35′		36°33′		36°02′		35°51′		36°49′		47°14′		49°52′	
	0°27′		2°15′		0°53′		1°28′		2°00′		3°00′		4°25′		5°06′		5°58′		9°15′		6°02′		2°20′	
	>2435		2700		30		>2000		>950		200		99		>874		ca.400		658		182		>100	
	25-VI-10		27-VI-10		4-IX-10		5-IX-10		5-IX-10		6-IX-10		6-IX-10		7-IX-10		8-IX-10		10-IX-10		17-IX-10		20-IX-10	
	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size
	1	11.5	7	6<11, 12	4	<10	4	2<10, 10, 12.5	.	..	.	..	20	9<12, 6 at 12-16, 4 at 18-26	2	7, 8	.	..	1	14	.	..	.	..
	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..
	.	.	.	.	1	10	.	..	.	..	.	..	1	11	.	..	1	18	.	..	.	..	.	..
	.	..	.	..	.	..	.	..	.	..	2	6.5, 11	.	..	.	..	.	..	.	..	.	..	.	..
	.	..	.	..	.	..	.	..	1	9	.	..	.	..	.	..	.	..	.	..	.	..	.	..
	.	..	.	..	.	..	2	16, 18	1	8.5	4	3<11, 14	.	..	.	..	.	..	.	..	.	..	.	..
0	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..
	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..
1, 15	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..
	.	..	1	8.5	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	2	29, 29	3	9, 9, 9
	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..
	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..
	.	.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..

...85.

b (continued). Su

Length of wire out	Locality	Atlantic; 85 off Portugal, 93, 94, 96 near Straits of Gibraltar								Alboran Sea; 98 in Str									
	Station	85		93		94		96		98		104		105		1			
	Position N.	38°22′		36°17′		36°06′		35°48′		35°57′		36°37′		36°43′		36			
	Position W.	9°28′		6°17′		6°02′		5°58′		5°35′		2°04′		2°08′		2			
	Depth in meters	>700		40		65		190		775		250		20		11			
	Date	17-VI-10		22-VI-10		23-VI-10		23-VI-10		23-VI-10		24-VI-10		24-VI-10		25-V			
meters	Species	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.			
150—300	*A. Thori* nov. nom.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	2	12		
	A. laterna, form B.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	.		
	A. imperialis (Raf.)	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	.		
	Symphurus lactea (Bonap.)	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	.		
1000—2000	*A. Thori* nov. nom.	.	..	.	..	.	..	.	..	.	..	.	.	.	..	1			
	A. laterna, form B.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.			
	A. Rüppeli (Cocco)	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.			

Length of wire out	Locality	Balearic Sea, from Algiers to N.W. of Corsica								Ligurian Sea						Tyrrhenian Sea				Eastern p of Balea		
	Station	113		115		118		121		122		123		124		126		129		133		
	Position N.	36°53′		38°17′		41°00′		43°08′		43°50′		44°14′		44°20′		42°43′		40°05′		38°18′		3
	Position E.	3°09′		4°11′		6°43′		8°05′		8°34′		8°55′		9°05′		9°50′		11°31′		9°59′		1
	Depth in meters	815		2800		>2700		>2500		1285		ca.700		86		588		3420		602		
	Date	28-VI-10		29-VI-10		1-VII-10		2-VII-10		2-VII-10		3-VII-10		3-VII-10		10-VII-10		12-VII-10		14-VII-10		19-
meters	Species	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No
0—50	*Bothus podas*	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	A. Grohmanni	.	..	.	..	.	..	.	..	.	..	.	..	.	..	1	7	.	..	.	..		2
	A. Thori	.	..	1	14	2	11, 13	2	10, 12	.	..	4	3<12.5, 20.5	.	..	3	8,9,16	.	..	6	<10	1	
	A. laterna, form A.	.	..	.	..	.	..	.	..	.	..	12	10<11, 18, 20	.	..	.	..	.	..	.	..		
	— — — B.	.	..	.	..	1	11.5	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	A. imperialis	.	..	1	10	.	..	.	..	.	..	.	..	.	..	.	..	.	..	1	7		
	A. Rüppeli	.	..	1	16	.	..	.	..	.	..	.	..	.	..	.	..	.	..	1	12		
65—100	*A. Grohmanni*	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		1
	A. Thori	.	..	1	20	.	..	.	..	.	..	6	7.5-10	.	..	.	..	.	..	.	..		
	A. laterna, form A.	.	..	.	..	.	×	.	..	.	..	6	8-10,14	101	80 < 10, 18 at 10-14, 3 at 15	.	..	.	..	.	..		
	— — — B.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	Solea lutea	.	..	.	..	.	..	.	..	.	..	.	..	2	4.5, 5.5	.	..	.	..	.	..		
150—300	*B. podas*	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	A. Thori	3	6,7,10	.	×	.	×	.	..	.	..	.	..	.	..	.	..	1	6	.	×		
	A. laterna	.	..	.	..	.	..	.	..	.	..	.	..	.	..	5	3<10 14, 18	.	..	.	..		
600-1200	*A. Thori*	.	..	.	×	.	..	.	..	28	26 < 12, 14, 16	.	..	.	..	.	..	.	..	.	×		
	A. laterna	.	..	.	..	.	..	.	..	45	39 < 12, 4 at 12.5-15, 18, 20	.	..	.	..	.	..	.	..	.	..		

1910.

	Off Algiers		Alboran Sea; Oran to Gibraltar						Atlantic—Channel; 229 mouth of Straits of Gibraltar; 248 Channel			
	108	112	221	223	224	225	227	228	229	233	245	248
	36°03′	36°56′	35°44′	36°13′	36°33′	36°35′	36°33′	36°02′	35°51′	36°49′	47°14′	49°52′
	0°27′	2°15′	0°53′	1°28′	2°00′	3°00′	4°25′	5°06′	5°58′	9°15′	6°02′	2°20′
	>2435	2700	30	>2000	>950	200	99	>874	ca.400	658	182	>100
	25-VI-10	17-VI-10	4-IX-10	5-IX-10	5-IX-10	6-IX-10	6-IX-10	7-IX-10	8-IX-10	10-IX-10	17-IX-10	20-IX-10
e	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size
10	4 3<12, 22	1 9	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..
8	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..
	. ..	. ..	. ..	2 17, 17	. ×	. ..	. ..	. ×	. ×	. ..	1 30	. ..
14	2 <9	. ..	. ..	. ..	. ..	. ..	. ..	1 9	. ..	. ..	. ..	. ..
10	. ..	. ..	. ..	. ×	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..
	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..

	Sidra Sea; 143, 144 on border of Ionian Sea						Levant	Aegean to Black Sea; 172, 173 Black Sea, 171, 175, 176, 178 Sea of Marmora							
	141	142	143	144	145	147	156	165	171	172	173	175	176	178	179
	36°42′	35°44′	35°18′	34°31′	32°38′	31°35′	32°24′	39°48′	41°07′	41°32′	41°17′	40°48′	40°45′	40°16′	40°02′
	13°34′	15°07′	16°25′	18°40′	19°02′	19°02′	26°51′	25°59′	29°05′	29°24′	29°11′	27°59′	27°04′	26°32′	25°55′
	530	98	1842	3340	1925	960	3000	35	60	1090	65	1103	560	70	85
	20-VII-12	22-VII-10	23-VII-10	24-VII-10	25-VII-10	25-VII-10	30-VII-10	5-VIII-10	10-VIII-10	11-VIII-10	11-VIII-10	11-VIII-10	12-VIII-10	12-VIII-10	13-VIII-10
	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size	No. Size
	. ..	. ..	2 20, 22	2 22, 22	2 19, 19	7 5—7	4 18-28	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..
	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	5 5—9	1 12	. ..	. ..	. ..	. ..	. ..
1	14.5	1 6.5	3 12.5 —15	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	4 6—12	. ..	. ..	. ..
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	. ..	. ..	. ..	. ..	. ..	. ..	. ..	1 19	. ..	1 5	1 10	. ..	1 7	5 3<10, 11, 19	3 6—9 11 9<10, 12, 14
	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ×	2 9, 9.5	2 9, 9.5	7 <10
	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	3 9,9,10	2 9.5,10	.
	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..
	. ..	. ..	1 21	. ×	. ×	. ×	1 22	. ..	. ..	. ..	. ..	. ×	. ..		. ..
	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..		. ..
	. ..	. ..	1 14	. ..	. ..	. ..	. ×	. ..	. ..	. ⁄	. ..	. ⁄	. ..		. ..
	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..	. ..		. ..

b (continued). Sum

Length of wire out	Locality	Aegean Sea				Ionian Sea; 184 Gulf of Corinth, 192 Straits of Messina								Tyrrhenian Sea; 193 Straits of Messi 200 S.E. of Sardinia							
	Station	182		183		184		185		186		192		193		194		199		2	
	Position N.	38°13′		37°52′		38°10′		38°12′		37°57′		38°07′		38°15′		38°33′		39°32′		39	
	Position E.	24°48′		23°09′		22°35′		21°17′		19°51′		15°35′		15°39′		15°29′		10°49′		10	
	Depth in meters	500		233		842		>50		>3000		652		>100		1140		ca.2700		2	
	Date	14-VIII-10		16-VIII-10		16-VIII-10		17-VIII-10		17-VIII-10		20-VIII-10		21-VIII-10		21-VIII-10		25-VIII-10		26-VI	
meters	Species	No.	Size	No.	Size	No	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	
0—50	*Bothus podas*	1	8.5	.	..	.	..	.	..	.	..	.	..	.	..	1	7	1	8.5		
	A. Grohmanni	.	..	.	..	.	..	.	..	.	..	.	..	1	5.5	.	..	.	..		
	A. Thori	.	..	.	..	1	15	3	<9	.	..	4	<9	.	..	.	..	.	..		
	A. laterna, form A.	.	..	.	..	.	..	.	..	.	×	.	..	.	..	.	..	.	..		
	— — — B.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	1	
	A. imperialis	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	A. Rüppeli	.	..	.	.	.	..	.	..	.	..	.	..	1	..	.	..	.	..		
	?*S. Capellonis*	.	..	.	..	.	..	.	..	.	..	.	..	.	7	.	..	.	..		
	Sym. lactea	.	..	.	..	.	..	.	..	.	..	4	7,8,12-13	6	<10	1	5.5	.	..		
65—100	*B. podas*	.	..	3	<7	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	A. Grohmanni	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	A. Thori	.	×	1	9.5	4	3<9,12.5	.	..	1	14	.	..	.	..	.	..	.	..		
	A. laterna, form A.	.	.	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
150—300	*B. podas*	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..		
	A. Thori	.	..	2	<8	.	..	.	..	.	..	.	..	.	..	.	..	3	12.5,13,16		
	A. laterna, form A.	.	..	.	..	.	..	.	..	.	×	.	×	.	..	.	..	.	..		
	A. Rüppeli	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	1	28		
	S. variegata Donov.	.	..	1	7	.	..	.	..	.	..	.	..	.	..	.	..	.	.		
600—2000	*B. podas*	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	.		
	A. Thori	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	.		
	A. laterna, form A.	.	×	.	..	.	..	.	..	.	×	.	..	.	..	.	×	.	×		
	A. Rüppeli	.	..	.	..	1	47	.	..	.	..	2	6.5, 7	.	..	.	..	.	.		

LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS

1910.

Balearic Sea; 207—215 Catalonian Sea, 220 off coast of Algiers

	205		206		207		208		209		210		211		213		215		216		217		218		220	
	39°16′		39°32′		39°58′		40°18′		40°34′		41°10′		41°17′		40°14′		39°14′		38°31′		38°01′		36°54′		36°25′	
	5°52′		5°15′		3°41′		3°20′		3°03′		2°23′		2°13′		0°54′		0°52′		1°24′		1°48′		2°57′		0°42′	
	ca.2860		ca.2860		64		>1600		>2000		780		150		75		~1050		>85		~2000		ca.2000		~350	
0	27-VIII-10		28-VIII-10		28-VIII-10		29-VIII-10		29-VIII-10		30-VIII-10		30-VIII-10		31-VIII-10		31-VIII-10		1-IX-10		1-IX-10		1-IX-10		1-IX-10	
	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No	Size	No.	Size	No.	Size
	.	..	8	7<10, 31	.	..	58	6—10	1	11	.	..	2	5.5, 7	.	..	.	..	3	5—7.5	.	..	1	36.5	.	..
	.	..	.	..	1	9	.	..	1	8	.	..	.	..	5	9—12	1	11	.	..	.	..	.	..	.	..
2	.	..	.	..	1	22	.	..	.	..	2	22,24.5	.	..	1	14	2	19.5,20	.	..	.	..	18	13<10, 13, 16.5, 18,18,20	3	5-11.5
	.	..	.	..	.	..	.	..	.	..	.	..	.	..	3	10,10.5,22	1	9	.	..	.	..	.	..	.	..
	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	.	..	1.	11.5
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	2	12, 17	.	..	.	..	.	..	1	6.5	.	..	.	..	.	..	2	9, 9.5	.	..	.	..	2	8, 9	5	6-10.5
	.	..	.	..	.	..	.	..	.	..	.	..	.	..	3	8—12	.	..	.	..	.	..	.	..	.	..
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II. Subfamily BOTHINAE

A. Genus ARNOGLOSSUS Bleeker

a. Historical summary

The name *Arnoglossus* dates from the 16th century (Rondelet, 1554) and was applied to one or other of two common Mediterranean forms, but it was not until 1862 that the name was definitely applied to this genus of the Rhombinae; previous to that time the genus had mostly been called simply *Pleuronectes*. Whilst the characters of the genus are well-known, the number of species it contains has always been a matter of dispute and though I am able to clear up some of the disputed points, one important matter has still to be left undecided. The difficulties are of two kinds. In earlier days, when the methods of capture and preservation were not good, a number of species were founded on imperfect specimens, which were more or less imperfectly described and badly figured. Thus, the earlier literature contains quite a number of forms, which apparently belong to the genus but cannot be referred with certainty to any one species. Hence there has been a general tendency to believe, that there were only two good species in European waters. On the other hand, now that excellent material can be obtained by modern methods, there still remains the question of the variability of a species; how far may a species be allowed to vary, before we divide it into two separate species? This is the position of the problem at the present time. The study of the postlarval specimens within recent years has proved, that 5 definite and distinct species of *Arnoglossus* inhabit the European waters and suggests, that there may be 6 or 7, but the adult forms closely resemble each other. Before stating the problem in more detail, it is advisable to glance at the earlier literature, to determine what names should be used for the different forms.

The honour of discovering and naming the first recognisable species of *Arnoglossus* has always been given to Walbaum (1792), but this is a mistake. Walbaum merely translated an erroneous descrip- ("Oculis dextris") by Pennant, who frankly states (1769, p. 191), that he had never seen the species and merely drew his own conclusions from a figure given by Ray, which had been reproduced from Willughby. In those days the figures were frequently reproduced in the reversed position and on referring to the original work of Willughby (1685, Pl. F. 8, fig. 7), we find that all the figures (of sole, turbot etc.) on the Plate in question had been reversed; hence the mistake of Pennant, which was repeated by Walbaum. The name also comes from Willughby. Pennant stated, that the species was known as lantern-fish in Cornwall, but Willughby states more definitely: "Haec forte Species illa est quam piscatores nostri Cornubiensis a pelluciditate sua a Lantern, id est Laternam vocant — — —." Whether the form described by Willughby was the same as the "*Arnoglossus* vel *Solea laevis*" of Rondelet and Gesner, I am unable to say, but Willughby's description and figure agree very well with the common, shallow-water form, now generally known as *laterna*. Risso's *P. Leotardi* (1810) and *R. nudus* (1826), both with the same fin-ray formula (D. 87, A. 60), were probably the same form, but, on the other hand, the "scald-fish", *Pl. casurus* of Hanmer in Pennant[1] (1812), is too imperfectly described to be recognised. The same applies to Risso's *R. candidissimus* (1826), which however may not have been an *Arnoglossus*. This species was based on a young, metamorphosed flat-fish of 60 mm. in length, "corpore candidissimo, rubro punctata, maxilla inferiore longiore." The fin-ray formula is given as D. 46, A. 28, but in the figure the dorsal and anal fins

[1] "We do not count the rays of the fins in this genus, not only because they are so numerous, but because nature hath given to each species characters sufficient to distinguish them by." — Pennant.

have been exchanged. It is useless to speculate upon the possible identity of *R. candidissimus*, but it may be menttoned, that RICHIARDI (1881) considered it the same as RAFINESQUE's *Bothus diaphanus* (1814), which EMERY (1883) has shown, was in all probability the young form of *B. podas*.

The second recognisable description of an *Arnoglossus* species dates from 1810, when RAFINESQUE-SCHMALZ gave a diagnosis of the form called by him *Bothus imperialis*. As this species has hitherto been overlooked by ichthyologists,[2] I may quote the principal points of RAFINESQUE's diagnosis. — "Quasi tre volte piu lungo che largo, ala dorsale principiando avanti gli occhi, linea laterale archeggiata alla base, lato sinistro liscio olivastro, nebulato di fosco bigio, lato dritto bianco, coda uguale.

"Oss. Si chiama *Tappa Impiriali* o *Linguata Impiriali*, egli e ancora migliore della Linguata per mangiara; ma rare volte se ne prende, perche vive sempre ne' fondi arenosi o fangosi del Mare e vi si nasconde sotto le arene o il fango; — — — ha il seguente numero di raggi all' ale, cioe, alla dorsale circa 100, all' anale circa 80, alla giugulare 8, alle pettorali 12, ed alla caudale 15."

It seems to me, that this diagnosis is quite sufficient to characterise the form described as an *Arnoglossus* and as one particular species of *Arnoglossus*. In the first place, the habit of an *Arnoglossus* is clearly indicated in: length 3 times the breadth, dorsal fin beginning in front of the eyes and arched lateral line; whilst in the second place, the formula D. ca. 100, A. ca. 80, can only refer to one species. A considerable number of the postlarval stages of this species are present in the "Thor's" collections from the Mediterranean and Atlantic.

Some years later, BONAPARTE (1838) founded the second species of *Arnoglossus*, the name of which at any rate has received general acceptance among ichthyologists, namely *A. Grohmanni*. The diagnosis given by Bonaparte is: "Pleuronectes ovatus griseo-fuscescens nebulosus, squamis majusculus deciduis; ore parvo, dentibus minutissimis; oculis mediocribus, superiore retroposito; radio secundo pinnae dorsalis valde elongato. D. 80, P. 10, V. 6, A. 52, C. 19." The specimens described were obtained from Sicily and one of the largest, about 4 inches in length, is figured; the number of scales along the lateral line in the figure is about 50. One cannot rely very much on the colour of these fishes but it is expressly stated, that the dorsal and ventral "profili" were darker than the rest, and this is also shown in the figure.

In 1861 CANESTRINI applied the same name, *Grohmanni*, to a form which had the second dorsal ray elongated, it is true, but had a somewhat different pigmentation and a very different fin-ray formula. CANESTRINI gives for his form D. 86—90, A. 60—67. All authors from that date have accepted CANESTRINI's fin-ray formula as applying to BONAPARTE's species. CANESTRINI's species has frequently been found; in fact, it is one of the most abundant forms in the Mediterranean and its distribution extends into British waters, but so far as I am aware, HOLT and CALDERWOOD (1895) are the only authors who have remarked on the discrepancy between BONAPARTE's fin-ray formula and that of the well-known form with the second dorsal ray elongated. They get over the difficulty by rejecting BONAPARTE's figures. It is quite true, that the Italian authors have not always been successful in determining the correct number of fin-rays, but I cannot find that this applies to BONAPARTE — quite the contrary. It seems to me, that the rejection of BONAPARTE's data can only hold good so long as we do not know any form to which they can be referred. The postlarval stages of such a form have now been taken by the "Thor" and the slight probability that BONAPARTE was wrong, changes to the great probability, that he was perfectly correct in his determination of the number of fin-rays in his form. In addition, there are other minor differences between Bonaparte's form and the species, which bears the name *Grohmanni* in other authors.

The species commonly known as *A. Grohmanni* must therefore give up the name it has usurped so long and a new name must be given it. I must admit, on the other hand, that I have no young or adult specimens corresponding to my postlarval stages, so that I cannot say positively, whether the adult

[1] Except by BONAPARTE, who included it as a synonym under *R. maximus* (1846) and by the American authors (1889), who recognised its similarity to the species described later by GÜNTHER under the name of *A. lophotes*.

of my series is the same as BONAPARTE's form and has the second dorsal ray permanently elongated. If it should prove, that the adult of my postlarval specimens does not have the second dorsal ray elongated, we have in any case to do with a new species and must reject the fin-ray formula given by BONAPARTE. Meanwhile, to my mind, the fin-ray formula entitles me to claim BONAPARTE's species as the parent of my postlarval specimens and I shall call the species commonly known as *A. Grohmanni* by the new name of *Arnoglossus Thori.* If my faith in BONAPARTE proves to be misplaced, then this name will still stand for a new species of *Arnoglossus,* the postlarval stages of which were discovered by the "Thor".

The next reference to a new species of Arnoglossus from European waters is the *Pleuronectes conspersus* of CANESTRINI (1861). This species was said to be very similar to "*Pleuronectes arnoglossus*" (*A. laterna*), but distinct from it in the following characters: "*P. arnoglossus*" has a larger mouth, the inferior maxilla being less than $8^1/_2$ times in the total length, wheres in "*P. conspersus*" it is more than $8^1/_2$ times. Further, in "*P. arnoglossus*" "pars ocularis cinereo-carnea, pinnis immaculatis," whilst in "*P. conspersus*" "Pars ocularis cinerea simul atque pinnis verticalibus punctis fuscis conspersus." The comparison was based on about 10 specimens of the two forms and both are stated to be common at Genoa though at different times of the year. The number of fin-rays was the same in both forms. SMITT (see later under *A. laterna*) was inclined to take *A. conspersus* as a good species and STEINDACHNER (1868) maintains it, though only for 1 specimen, but VINCIGUERRA (1883), MARION and HOLT (1899) have considered it the same as *A. laterna.*

As will be shown, CANESTRINI was perfectly right in his facts; the two forms he describes are easily distinguishable, but he placed the names wrongly. The spotted form is really the common *laterna* of WILLUGHBY and the northern waters.

In 1862 GÜNTHER presented the new species *Arnoglossus lophotes* to the world of ichthyologists, who in Great Britain at any rate have been more inclined to reject than to accept it. The remarkable history of this species will be discussed below, but meantime it may be said, that no new species has been added to the genus *Arnoglossus* since 1862. Excluding *candidissimus, nudus, Leotardi* and *conspersus,* we have thus found 3--4 species of *Arnoglossus,* the adults of which have been mentioned or described in the literature, namely, *A. laterna* Willughby, *A. imperialis* (Rafinesque), *A. Grohmanni* (Bonaparte) and *A. lophotes* Günther. The first and third have been generally recognized as good species, the second has been overlooked and is really the same as the fourth. As mentioned above, there are at least 5 species of *Arnoglossus* in the collections of the "Thor", so that more names have still to be found. In the further search for these, we may turn to the references in the literature to the larval and postlarval stages of possible *Arnoglossus* species.

So far as I have been able to find, the first mention of a postlarval form (i. e. one in which the migration of the eye is not complete), which may be accepted as belonging to one or other species of *Arnoglossus,* is contained in the letter of COCCO[1] to his friend AUGUSTO KROHN of Livonia (1844). Here a description and figure are given of a postlarval fish between 30—40 mm. in length, to which was given the name *Peloria Rüppelii.* The description agrees well with the largest of the forms taken by the "Thor", when allowance is made for a slight difference in the number of dorsal fin-rays.[2] The same form[3] was described later by FACCIOLÀ (1885) under the name of *Charybdia Rüppelii,* and FACCIOLÀ also added a new species *Charybdia rhomboidichthys* with a smaller number of fin-rays (D. 99, A. 74, P. numerosi, V. 6). The length of the specimens of the latter species was about 40 mm. and the author mentions among the other characters that "la ventrale sinistra e piu lunga della destra". This form has also been taken by the "Thor" and is clearly the young postlarval stage of RAFINESQUE's *Bothus imperialis.*[4]

[1] For a copy of this letter I am indebted to Prof. PAUL MAYER of the Naples Station.

[2] Cocco gives: D. 118; V. 5 (in the figure 6); A. 90; P. — — —; C. 18. FACCIOLÀ gives D. 113; A. 91, P. numerosi, V. 9 circa.

[3] In 1883 EMERY applied the name *Peloria Rüppelii* Cocco to a totally different form, as pointed out by RAFFAELE (1888).

[4] It need hardly be recalled, that Cocco believed his *Peloria* to be a distinct genus of fishes, in the same way as the Leptocephali were for long thought to be independent species. FACCIOLÀ seems to have maintained the same belief partly from habit, partly from erroneous observation. His genus *Peloria,* for example, is based on "una sola ventrale," which is supposed to have 13 rays. It is not to be wondered at, that "la Peloria Heckelii non puo confondersi con nessun Pleuronettide conosciuto."

In 1888 GRÆFFE gave a figure of a small postlarval form, which he ascribed to *A. Grohmanni.* It may have been *A. Grohmanni,* but the characteristics are not stated and the figure is useless for identification. In the same year RAFFAELE published his well-known work on the pelagic eggs and larvae taken in the Bay of Naples and in this we find the description and figures of two incomplete series of *Arnoglossus* larvae, which are referred with some doubt to *A. laterna* and *A. Grohmanni.*

For further reference to the early stages of *Arnoglossus* we may now turn to the northern literature. In 1893 HOLT gave a figure of a young *A. laterna* 25 mm. long, taken west of Ireland, in which metamorphosis was complete and scales present. A year later PETERSEN published an outline figure of an *A. laterna,* taken off the coast of Norway, which was also completely metamorphosed but was only 23 mm. long. The scales were already present at this size.

The first complete account of the developmental history of an *Arnoglossus* species was given by EHRENBAUM in 1897. From material collected near Heligoland, EHRENBAUM was able to describe in detail all the different stages of *A. laterna* from the egg until metamorphosis was complete, about 18—20 mm. As this work will be frequently cited in the sequel, it is unnecessary to refer to details here, but it may be noticed, that the observations of HOLT, PETERSEN and EHRENBAUM are in agreement on one very essential point, namely, that the metamorphosis in *A. laterna* must be complete about 20 mm. As will be seen later, this is a very important character in distinguishing the very closely allied, postlarval stages of the different species of *Arnoglossus.*

In addition to the above, HOLT (1897, 1899) has also described the eggs and early larvae of other *Arnoglossus* species, which were taken partly at Marseilles, partly on the south coast of England. The former are referred to *A. Grohmanni,* the latter in part to *A. laterna* (eggs), in part to *A. Grohmanni,* (larvae). HOLT himself remarks on the differences in both cases, but it may be recalled, that he did not believe in the existence of *A. lophotes* as a separate species. There is reason to suppose, however, that the Plymouth forms belonged in reality to the so-called *lophotes* form, which is common near Plymouth and which HOLT also mentions in connection with these eggs and larvae.

The search through the literature of the young forms has thus added a fifth species (*Rüppeli* (Cocco)) to the three species of *Arnoglossus* already found. Further papers on the postlarval forms have still to be cited, but it is more convenient at the present point to ascertain the proper application of the various names to the different species, and for this purpose we may turn to the history of GÜNTHER's species *A. lophotes.*

The advent of *A. lophotes* into ichthyological literature, its attempted banishment by DAY, CUNNINGHAM, HOLT and CALDERWOOD and its apparent restoration by COLLETT and PETERSEN form a most interesting chapter in the history of this genus. The original diagnosis of the species given by GÜNTHER (the principal characters distinguishing it from *A. laterna* and *A. Grohmanni* being the more elongated form of the body, relatively smaller head and mouth, larger number of fin-rays and the anterior dorsal rays elongate) was based on 3 dried skins, the origin of which was doubtful. Although the specific differences seem as good as one could wish for, the absence of definite specimens and lack of information with regard to the range of variation of the different species, not to mention of the young specimens, led to a great deal of uncertainty and controversy. In preparing his work on the "British Fishes" DAY refused to acknowledge the species and even went so far as to say, that the specimens on which GÜNTHER's diagnosis was based were identical with *A. Grohmanni* (1882), though he had seen one entire specimen taken in the Bristol Channel, which was admittedly a *lophotes* according to GÜNTHER. At that time, however, *A. Grohmanni* was not known to occur in the British waters. In 1890 the controversy reached an acute stage, when GÜNTHER once more maintained the separate existence of the species and CUNNINGHAM (1890) just as earnestly maintained, that *lophotes* was only a stage of another species, not *Grohmanni* this time but *A. laterna.* On the south-west coast of England CUNNINGHAM found the *lophotes* form in abundance along with

laterna, the former being always older (larger) and males, the latter being younger or females. CUNNINGHAM concluded from this, that the *lophotes* characteristics were really sexual and belonged to the males of over 13—14 cm. in length.

The evidence brought forward by CUNNINGHAM appears to have been conclusive, at least no response was made by GÜNTHER, and the fate of *lophotes* seemed finally decided, when HOLT and CALDERWOOD (1895), though fully aware that BOULENGER also shared the view of GÜNTHER, made an exhaustive examination of the *lophotes* and *laterna* forms and came to the same final conclusion as CUNNINGHAM (1890). COLLETT (1896) has more recently revived *A. lophotes* for some specimens taken by the Prince of MONACO near the Azores, but as he was in ignorance of HOLT and CALDERWOOD's work, this revival was rather in the nature of an accident.

The first, substantial indication, that something was radically wrong in the conclusions of CUNNINGHAM and HOLT, is contained in the work of PETERSEN (1909) on the early stages of the genus *Arnoglossus*. In the extensive material brought home by the "Thor" from the Bay of Biscay and the waters round the British coasts, PETERSEN found a number of postlarval specimens of Arnoglossus, which could not be referred to *A. laterna*. The latter, as already mentioned, had become well-known through the investigations of EHRENBAUM. PETERSEN was thus obliged to revive *lophotes* or found a new species. As a matter of fact, however, PETERSEN's material contained 2 undescribed forms of postlarval *Arnoglossus*, neither of which apparently could be referred to *laterna*, and PETERSEN provisionally and with great hesitation called the one series *lophotes*, the other *Grohmanni*. The specimens of both series were taken in the waters of Western Europe, not in the Mediterranean.

PETERSEN's investigations have thus brought us back to GÜNTHER's position in 1890, but unfortunately we cannot stop there. The second series of postlarval *Arnoglossus*, which PETERSEN provisionally referred to *Grohmanni*, do not belong to *Grohmanni* at all, are in fact very distinct from the true postlarval stages of the so-called *A. Grohmanni*. In pigmentation, number of vertebrae etc. they are more nearly related to *A. laterna*. What then are PETERSEN's 2 series and which of them is to be called *A. lophotes* Günther? Supposing that PETERSEN had known the larval stages of the so-called *A. Grohmanni*, what names would he have given to his 2 series of postlarvae?

It seems worth while putting forward these questions. In the first place, the two series of postlarvae are quite distinct from one another, the larger form coming nearer to *A. Grohmanni* (so-called), the smaller form (PETERSEN's *Grohmanni*) to *A. laterna*. In the second place, both forms agree with the account given by GÜNTHER of *lophotes* in the number of fin-rays, and in these characters as well as number of vertebrae fall within the range of variation given by HOLT and CALDERWOOD for their one species *A. laterna*. We thus have to find a name for PETERSEN's supposed *A. Grohmanni*.

As will be shown, the matter is very complicated. Provisionally I take *A. laterna* as a variable and compound species, embracing not only CANESTRINI's 2 species *conspersus* and *arnoglossus* (adults), but also several different postlarval forms (EHRENBAUM's *A. laterna*, PETERSEN's *A. Grohmanni* and others).

On the other hand, there is no doubt, that PETERSEN's larger series (so-called *A. lophotes*) agrees with the *Bothus imperialis* of RAFINESQUE and *Charybdia rhomboidichthys* of FACCIOLÀ, as also with the larger form included under *A. laterna* by CUNNINGHAM, HOLT and CALDERWOOD.

Lastly, it may be mentioned, that COLLETT (1896) also makes a brief reference to a postlarval specimen of a flat-fish, 25 mm. in length and 11 mm. high, taken by the Prince of MONACO to the south of the Azores. COLLETT recognises the similarity of his specimen to the *Peloria Rüppeli* of COCCO. As already mentioned, this same form is present in the material collected by the "Thor" and several metamorphosed specimens prove, that it is without doubt an *Arnoglossus*. Further, the careful description given by SCHIÖDTE of his "*Bascanius tædifer*" (1868) leaves no doubt, that he also had the same form.

This review of the literature shows, that many species of *Arnoglossus* have been described from

time to time. Of all these species not one has hitherto been clearly defined or generally accepted; the commonest in northern waters (*A. laterna*) has been confused with at least one other species; the commonest in the Mediterranean (the so-called *Grohmanni*) has borne a wrong name most of the time; the postlarval stages of the true *Grohmanni* have just been found to vindicate the correctness of BONAPARTE's data; a fourth species has been overlooked for nearly 100 years; a fifth has only been known hitherto in the postlarval stages and that under a different name; whilst a 6th and possibly a 7th are still possibly concealed under the common form *A. laterna*. It would be difficult to find a parallel to this state of things in any other common group of fishes.

b. Specific characters of ARNOGLOSSUS

As shown above, we can find support in the literature for the founding of 6 different European species of *Arnoglossus*. I have come to the conclusion, however, that provisionally we must be content with 5, not because my material does not contain representatives of the possible 6 species; on the contrary, it suggests, if anything, the existence of more than 6 species, according to our judgment of the specific characters.

The 5 distinct species of *Arnoglossus* in European waters are:

A. Grohmanni (Bonap., non auctorum)

A. Thori (= *A. Grohmanni* auct.)[1]

A. laterna Will.

A. imperialis (Raf. = *A. lophotes* Gtr. et auct.)

A. Rüppeli (Cocco).

The most variable species is *Arnoglossus laterna* and this I subdivide provisionally as follows:

A. laterna, var. *macrostoma*

A. laterna, var. *microstoma*, forma *vulgaris*

— " *biscayensis*.

Such a subdivision for a marine species of fish is quite unique, recalling the many *formæ* of the lower plankton species. It will be shown, however, that *A. laterna* through its different forms is perhaps just as good an indicator of different "waters" as any plankton species. So much is this the case, that a sample containing a few postlarval specimens in the metamorphosing stages or a little earlier or later can be referred without looking at the label to definite areas, for example, Bay of Biscay, western Channel, southern or north-east North Sea. And the very few exceptions which are present in my material suggest rather the presence of currents of water from other localities.

Before discussing the characters which form the basis of the above classification, it may be well to recall here the various references in the literature to the variability of *A. laterna*. As mentioned in the previous section CANESTRINI (1861) was the first to notice, that the *Pleuronectes arnoglossus* or *Arnoglossus laterna* of authors was not a simple species. CANESTRINI, in fact, distinguished between 2 species and in spite of the scepticism of later authors (GIGLIOLI, VINCIGUERRA, MARION, HOLT) my material fully confirms CANESTRINI's conclusions, except in one very important particular. The difference in the size of the head and mouth undoubtedly distinguishes these two forms, but as the name *conspersus* indicates, CANESTRINI laid chief weight on the colouration. This was an unfortunate mistake, which must be ascribed to the fact that earlier authors and even the later have not given a proper description of the *laterna* of northern waters. And this faulty description is to be referred again to the fact, that *A. laterna* has shed most of its skin and scales, before it comes into the hands of observers. There are very few figures of *A. laterna*, for example, which give the course of the lateral line correctly. But, when attention is specially directed to the matter, we find that the *A. laterna* of northern waters (e. g. North Sea and Channel) always has

[1] For the evidence that *A. Grohmanni* auct. is not the same as BONAPARTE's species, see later under this species.

spots on the body and especially on the fins. Further, the northern form has the smaller head and mouth. Consequently, according to CANESTRINI's definition, the northern form should be *conspersus*. I do not think, however, that CANESTRINI's names can be maintained. In the first place, the northern form is by priority *laterna* and in the second place, the "spottiness" is not a good specific character. The spots are most marked in the younger specimens (also in *A. Thori*), but in the larger specimens and in many of the smaller they are so faint, that one may be pardoned for overlooking them. Further, in 2 specimens (Thor St. 142) which have the "*arnoglossus*" head and mouth (according to CANESTRINI), the *conspersus* markings are quite distinct on the fins.

It was thus unfortunate, that CANESTRINI raised this characteristic into prominence. The principal distinctive characters are undoubtedly the head and mouth and here it may be recalled, that SMITT (1892) was disposed to believe, that the "*P. arnoglossus*" of CANESTRINI does not occur in northern waters. This is also true, so far as my material goes, but it cannot be said, that SMITT is very convincing with his evidence. He compares only 3 Mediterranean specimens with only 2 specimens from the Skager Rak and distinguishes between: A. forma *macrocephala*, with length of head ca. 24% of total length of body, height of body ca. 28% do.; B. forma *microcephala* with head ca. 19—23% of length of body and height ca. 33—35% do. If SMITT had only 2 specimens from the Skager Rak, then in one of them the head must have been ca. 23% of the total length, thus less distant from the 24% of the Mediterranean specimens than the 19% of the other Skager Rak specimen. Further, the differences he mentions for the height can only be taken as accidental, with such a small material; they are not present in my larger material.

COLLETT (1879) has also compared Mediterranean and northern specimens of *A. laterna* and could find no essential difference between them. This is quite a sound conclusion, for the same form "*vulgaris*" appears to be the common form in the Mediterranean and North Sea. Nevertheless, COLLETT has obviously not seen any specimens of CANESTRINI's "*P. arnoglossus*", which can usually be distinguished at first glance from the true *laterna* of northern and Mediterranean waters. It is evident, that the Italian authors (GIGLIOLI and VINCIGUERRA (1883)) have not seen CANESTRINI's *P. arnoglossus* either.

HOLT and CALDERWOOD's confusion of *A. laterna* with *A. imperialis* (*lophotes* Gthr.) may also be mentioned here, as indicating the necessity of determining the true specific characters and the necessity also of having a large material. HOLT and CALDERWOOD found, that these two species could not be distinguished by the dimensions of the body, head or mouth, nor by the marks or colouration. On the other hand, they failed to recognise the specific value of differences in the number of vertebrae and fin-rays, their material being too small and imperfect (though amounting to about 50 specimens in all) to be convincing to them.

The chief advantage of this study of the literature is, that it shows the necessity of determining what are the specific characters within the whole genus; it is not sufficient to separate small groups of specimens by means of one or two isolated characters, as CANESTRINI and SMITT have done, for example, nor again to combine other groups of specimens (CUNNINGHAM, HOLT and CALDERWOOD) owing to their great resemblance in some characters.

To give the different characters their due weight, it is necessary to have a very large material, if possible of all the species, but more especially of the more variable species. My material comprises many hundred specimens altogether, yet it is not large enough to satisfy all requirements. This applies more especially to *A. laterna*, sens. lat., of which I have examined about 400 specimens, adult and postlarval stages. Possibly a larger material of the northern and Mediterranean forms of *A. laterna* would have enabled me to raise one to the rank of a distinct species, but for the time being the available material does not permit of this being done.

The material to be analysed consists of the following:

	From	Postlarval specimens	Adults
A. Grohmanni (Bonap.)	Mediterranean	15	
A. Thori nov. nom.	—	45	67
A. laterna Will.			
var. *macrostoma*	—	[1]	9
— *microstoma*	—		11
	Bay of Biscay	55	
	Channel	75	49
	S. North Sea	90	33
	E. North Sea and Kattegat	51	27
A. imperialis	Mediterranean	7	
	Channel	6	74
A. Rüppeli (Cocco)	Mediterranean	9	
	Total number of specimens	623	

The specific characters may be considered under 4 groups: (1) structural characters, including colouration and peculiarities; (2) dimensional characters, which can be subjected to measurement; (3) numerical characters, which have to be counted; aud (4) the postlarval characteristics.

(1) Structural characters of *Arnoglossus*. In structure the different species of *Arnoglossus* show an extremely close affinity to each other. Of outstanding structural differences, such as distinguish *P. flesus*, *P. platessa* and *P. microcephalus* at a glance, for example, there are none. The form is the same, the fins arise and terminate at the same place (except perhaps in *A. Grohmanni* Bonap.) and the scaly covering in all is usually conspicuous by its absence. All the species are small, though there seems to be a difference in the maximum size attained; thus, *A. imperialis* reaches a length of over 20 cm. and specimens of 16—20 cm. are common; my largest specimen of *A. laterna* is 16 cm. but from 10—13 cm. are the commonest sizes; the largest specimen recorded of *A. Thori* was 15 cm., but the common sizes are about 10—12 cm. This character is also connected with the size at first-maturity, i. e. when the species spawns for the first time; thus, *A. imperialis* does not appear to become mature until it reaches a length of about 13 cm., whereas both *A. laterna* and *A. Thori* are mature already at a length of 7—8 cm. Lastly, the greater size of *A. imperialis* is accompanied by a thickness or fleshiness of some marketable value, whereas *A. laterna* and *A. Thori* are seldom more than a thin framework of bones. Of *A. Grohmanni* (Bonap.) and *A. Rüppeli* (Cocco) I have not yet seen the adult specimens.

The colouration is also not distinctive; as a general rule, the ground colour is greyish or yellowish, sometimes even reddish, but the shades are exceedingly variable, from light yellow to very dark grey, almost brown. In some cases the dark colouration may be ascribed to preservation, but to judge from fairly fresh material the larger or older specimens are darker than the smaller and the dark markings are more conspicuous.

The dark markings on the body consist of a darker shade of grey or brown about the arch of the lateral line, another halfway along the straight portion of the lateral line and a third or even a fourth spot nearer the tail. These darker shades have the form of diffuse patches spreading out towards the interspinous regions or they may be concentrated into definite spots or not visible at all. Of the 3 species mentioned, *A. Thori* is the one which has these dark patches most marked, *A. laterna* the least, though in one large specimen of the latter from the Skager Rak the markings were of a coal-black colour. In any case all three species may or may not show these markings, and all that can be said is, that *A. laterna* (both varieties) is generally lighter coloured than the others (compare text-figures 7, 8, 9, 10).

[1] The postlarval specimens of *A. laterna* taken on the Mediterranean cruises of the "Thor" are not included here.

The presence of a fine sprinkling of small dark spots over the body and especially the fins is not peculiar to one species. *A. Thori* is perhaps best favoured in this respect, but similar spots are to be seen in large specimens of *A. imperialis* and in all the forms of *A. laterna.*

In the mature males of *A. Thori* and *A. imperialis* there is a distinct black mark on the left ventral fin, extending over the membrane of the 4th to 6th rays and most conspicuous, naturally, on the large *A. imperialis.* The females also have a dark mark at the same place, but it is very faint. The males of A. *laterna* may also show this black spot on the left ventral; at least it is present in all the larger specimens from Plymouth, in one specimen of the pale, large-mouthed variety from the Mediterranean, and in several from the Kattegat. On the other hand, it is not to be seen in many specimens from the Mediterranean and North Sea, nor in 2 specimens from the Kattegat. It thus seems very variable in *A. laterna.*

On the whole, therefore, the colouration like the general structure is not distinctive and can hardly be used as a specific character. On the other hand, there are certain peculiarities or eccentricities of structure, which are most valuable in the separation of the species. As is well-known, the 2nd dorsal ray in *A. Thori* (= *A. Grohmanni* auct.) is greatly elongated, with a broad, pennate membrane attached to it. This peculiar structure has nothing to do with age or sex, as CUNNINGHAM thought (1890); it is present in both sexes and is already conspicuous in young specimens from 30 mm. onwards. In *A. laterna* there is no appreciable elongation of the dorsal rays, not even in the largest specimens. I have examined 10 male specimens between 13 and 16 cm. and compared the 2nd and 3rd dorsal rays with the 6th. A difference of 1 to 1.5 mm. could be detected, but no more. In the males of *A. imperialis* of the same length, however, also of course in the larger, the 2nd and 3rd rays are about twice the length of the 6th and 7th rays, and the 4th and 5th rays are also longer than the latter. In the females of *A. imperialis,* on the other hand, the 2nd to 5th dorsal rays are only a little longer than the 6th and subsequent rays. In this species, therefore, the elongation of the dorsal rays would appear to be a secondary sexual character, which is not the case in the other species.

In *A. imperialis* again the left ventral is relatively longer in the mature males than in the mature females, the difference being quite appreciable — 2 to 3% of the total length of the fish. At what size these sexual differences arise in *A. imperialis* I am unable to say, but they are certainly present already at 13—14 cm., at which size there is practically no sign of them in *A. laterna.* Lastly, it has to be mentioned, that BONAPARTE in his figure of *A. Grohmanni* makes the 2nd dorsal ray about twice as long as the others, but does not give it the broad, black membrane, which we always find in well-preserved specimens of *A. Thori.* It is probable, therefore, that the adults of the true *A. Grohmanni* have the 2nd D ray simply elongated as in *A. imperialis.*

Summing up, it appears that the only structure, which is of specific importance in *Arnoglossus,* is the long and broad 2nd dorsal ray in *A. Thori.* But for the presence of this structure it would be impossible to separate *A. Thori* from *A. laterna.* The elongated dorsal rays in *A. imperialis* and elongated ventral in this species can also be used to distinguish it from other species (so far as we know at present, but the condition in *A. Rüppeli* is not yet known), though here the character is more sexual than specific.

(2). Dimensional characters. I have taken measurements of 10 different characters in *A. Thori, A. laterna* and *A. imperialis* and may just briefly summarise the results.

1. Greatest height without the vertical fins:

a. *A. Thori* (16 spec.)	32—38%	of total length
b. *A. laterna*		
var. *macrostoma* (9 spec.)	30—35%	- —
— *microstoma* (52 spec.)	19—36%	- —
c. *A. imperialis* (74 spec.)	31—36%	- —

2. Distance of greatest height to beginning of caudal fin (not a good character to measure, but it gives some notion of the more or less elongated form of the fish):

a. *A. Thori* (15 spec.) ..... 111—140% of greatest height
b. *A. laterna*
var. *macrostoma* (9 spec.) ..... 127—152% - — —
— *microstoma* (49 spec.) ..... 121—155% - — —
c. *A. imperialis* (73 spec.) ..... (125) 134—155% - — —

Whilst the variation is very great, as was to be expected in such an indefinite character, it looks as if this dimension might prove useful in helping to define the form of a flat-fish. As will be shown later, the corresponding dimension in *Bothus podas* is 87—98%. Taking the posterior half of the body to represent half an ellipse, then the

$$\frac{\text{major axis}}{2 \text{ minor axis}} = \text{ca. } 124\% \text{ in } A.\ Thori$$

ca. 140% in *A. laterna*
ca. 145% in *A. imperialis.*

Since the proportion: greatest height to total length is practically the same in all 3 species, this means that the greatest height approaches nearer the head, i. e. lies more over the abdominal region, in the latter species. Without more measurements, however, particularly of *A. Thori* and *A. laterna* var. *macrostoma*, it is not profitable to analyse the data further. As a specific character the dimension has hardly any value by comparison with the more important fact, of which it is merely the external expression, that the number of caudal vertebrae forms an increasing series from *A. Thori* to *A. imperialis.*

3. Length of the tail, i. e. longest ray in caudal fin:

a. *A. Thori* (spec.) ..... 16—18% of total length
b. *A laterna* (46 spec.) ..... 15—18% - — —
c. *A. imperialis* (74 spec.) ..... 15—17% - — —

4. Length of the head (this dimension can be measured with very great accuracy, if instead of the usual snout to edge of operculum we measure the distance from the snout, premaxilla firmly closed, to the first scale of the lateral line on the body, i. e. to the posterior edge of the posttemporal. In this way a very firm support is obtained for the pointers at both ends and the slight variation in the dimension is an index of its reliability):

a. *A. Thori* (11 spec.) ..... (18) 19—21% of total length
b. *A. laterna*
var. *macrostoma* (9 spec.) ..... (20) 21—22% - — —
— *microstoma* (101 —) ..... (17) 18—20 (21)% - — —
c. *A. imperialis* (74 spec.) ..... 17—18 (19)% - — —

The numbers in brackets indicate, that only one or two such cases occur. When we consider the great reliability that can be placed on this dimension, it may be concluded, that these differences between the species are of some significance. As shown on an earlier occasion however (1900 a), the length of the head in flat-fish is subject to changes due to growth, sex and maturity, so that the differences shown would have to be analysed more closely, before being accepted as specific differences. As the sexes are in fairly equal proportion and almost all the specimens taken into consideration are mature, the only factor that need be considered here is that of growth. Now the great majority of the *A. imperialis* specimens are over 16 cm., whilst the majority of the *A. laterna* are less than 13 cm. and of *A. Thori* less than 10 cm. As the relative size of the head decreases with growth, we see, that the length of the head in *A. Thori, A. laterna* var. *microstoma* and *A. imperialis* is practically the same. On the other hand, the relative length of the head in *A. laterna* var. *macrostoma* seems undoubtedly to be greater. This can be seen better from a comparison of the absolute measurements.

Thus, at each of the sizes considered, there is an average difference between the two varieties of about 2 mm. As the error of observation does not amount to more than .5 mm., the difference is important, even though we are only dealing with 9 specimens of the variety *macrostoma*. It will be shown below, further, that this difference is associated with a much greater difference in the size of the mouth.

	Total length	No. of spec.	Length of head
var. *macrostoma*	13 cm.	2	26.5, 27 mm.
— *microstoma*	13	5	24, 24, 24, 25, 25.5 mm.
— *macrostoma*	10	2	22, 24 mm.
— *microstoma*	10	5	18, 18, 19, 19, 19 mm.
— *macrostoma*	9	3	19, 19.5, 20.5 mm.
— *microstoma*	9	7	17, 17, 18, 18, 18, 18, 19 mm.
— *macrostoma*	8	2	17, 18.5 mm.
— *microstoma*	8	6	15, 15.5, 15.5, 15.5, 16, 16 mm.

5. Length of the left pectoral. This was measured chiefly in *A. imperialis*, to determine whether sexual differences were present. In both sexes of this species, however, the dimension was 13—15% of the total length and also the same in 8 specimens of *A. Thori* and 10 specimens of *A. laterna*.

6. Length of left ventral. This was also chiefly measured in *A. imperialis;* in 14 males the left ventral was 9—12% of the total length, in 14 females 6—8% of the total length. The latter was the proportion in 5 specimens of *A. laterna*.

7. Length of anterior dorsal rays:

a. *A. Thori* 2nd dorsal ray greatly liable to injury; when complete, in both male and female from 21 to 24% of total length or a little longer than the head.

b. *A. laterna* (3rd ray) ♂ (14 spec.) ..... 6—9% of total length
♀ (3 spec.) ..... 5—6% - — —

c. *A. imperialis* (3rd ray) ♂ (13 spec.) ..... 15—17% - — —
♀ (14 spec.) ..... 6—10% - — —

8. Length of the upper orbit (measured from the bony ridge in front to the posterior prominence behind; it is not a reliable measurement but preferable to the eye-ball):

a. *A. Thori* (21 spec.) ..... (32) 34—39 (42)% of length of head

b. *A. laterna*
var. *macrostoma* (9 spec.) ..... 29—36 - — - —
microstoma (60 spec.) ..... (27) 29—38 (39)% - — - —

c. *A. imperialis* (72 spec.) ..... 35—41 % - — - —

9. Length of the mandible (measured on the left branch, from end to end, a very reliable measurement).

a. *A. Thori* (21 spec.) ..... (47) 50—56 % of length of head

b. *A. laterna*
var. *macrostoma* (9 spec.) ..... (59) 61—67 % - — - —
microstoma (97 spec.) ..... 50—56 (59)% - — - —

c. *A. imperialis* (74 spec.) ..... (48) 50—55 (57)% - — - —

As with the length of the head, the relative length of the mandible is the same in *A. Thori, A. imperialis* and *A. laterna* var. *microstoma;* in *A. laterna* var. *macrostoma*, however, the mandible is no less than 10% greater on an average. Since the head is also larger in the latter form, this means naturally, that the mandible is very much greater absolutely.

10. Length of the premaxilla (measured on the left side. The measurement of this dimension demands considerable care, as the lower end of the bone is only a fine splint covered by thick skin. With care, however, the measurement gives very accurate and reliable results).

a. *A. Thori* (21 spec.) ..... 30—36% of length of head
b. *A. laterna*
var. *macrostoma* (9 spec.) ..... 41—46% - — - —
microstoma (97 spec.) ..... 34—40 (42)% - — - —
c. *A. imperialis* (74 spec.) ..... 29—36% - — - —

As might be expected, there is no appreciable difference between the 3 species, except in the case of *A. laterna* var. *macrostoma*, which has a distinctly larger premaxilla than the other forms — all the larger because the head is relatively larger. If, now, we take the absolute measurements of both the mandible and premaxilla, as has been done for the length of the head, the differences between var. *macrostoma* and var. *microstoma* become even more prominent.

	Total length	No. of specimens	Length of mandible mm.	Length of premaxilla mm.
var. *macrostoma*	13 cm.	2	17.5, 18	12.5
— *microstoma*	13 —	5	12, 12.5, 13, 13.5, 14	8.5, 9, 9, 9.5, 10
— *macrostoma*	10 —	2	14, 15	10, 11
— *microstoma*	10 —	5	10, 10, 10, 10, 10.5	6.5, 6.5, 7, 7, 7
— *macrostoma*	9 —	3	11.5, 12, 12.5	8, 8, 9.5
— *microstoma*	9 —	7	9, 9.5, 10, 10.5, 10.5, 10.5, 11	6, 6.5, 6.5, 7, 7, 7, 7.5
— *macrostoma*	8 —	2	10, 11.5	7.5, 8
— *microstoma*	8 —	6	8, 8.5, 8.5, 8.5, 9, 9	5.5, 5.5, 6, 6, 6, 6

It is impossible to disregard these differences, which amount to from 3 to 4mm. in the larger specimens and to about 2 mm. in the smaller in both dimensions. Further, when specimens of the same size are directly compared, the difference is obvious at a glance, as the accompanying sketches show.

Summing up with regard to the dimensional characters, we see, that the 3 species *A. Thori, A. laterna* var. *microstoma* and *A. imperialis* are practically identical in all the characters examined. Fine differences there are, which can be displayed by the average of the measurements on a large number of specimens; for example, the upper orbit is generally greater than the premaxilla in *A. Thori*, less in *A. laterna* (see later under *laterna*), but such fine differences cannot be used for general systematic purposes. The only specific characters discovered so far, are the elongated 2nd dorsal ray in *A. Thori* and the elongated 2nd-5th dorsal rays in *A. imperialis*, the latter of which is more a secondary sexual character. In all proportions and in structure the 3 species are almost precisely alike. This fact makes the large mouth and head of *A. laterna* var. *macrostoma* all the more remarkable. Whether this entitles us to raise the variety *macrostoma* to the rank of a separate species, will be discussed later under *A. laterna*.

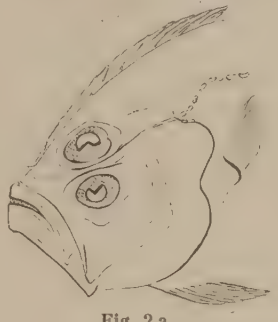


Fig. 2 a.
A. laterna var. *macrostoma*
nat. size.
Total length — 13 cm.

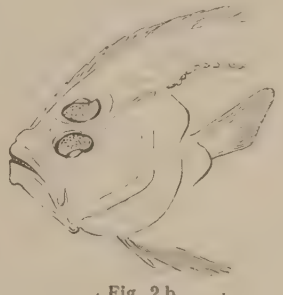


Fig. 2 b.
A. laterna var. *microstoma*
nat. size.
Total length — 13 cm.

(3) Numerical characters of *Arnoglossus*. In flat-fishes at any rate the numerical characters, vertebrae, fin-rays etc., usually offer the most important specific characters, and here the postlarval specimens can also be utilised. There is no support for the suggestion, namely, that the number of vertebrae or fin-rays may increase during the growth of the fish and, as a matter of fact, the counting of the vertebrae and fin-rays is if anything more easily carried out in the postlarval specimens than in the adults. The identification of the postlarval specimens will be discussed later; it need only be said here, that there is no difficulty in distinguishing the 5 main species.

For the sake of comparison I have counted the number of rays in the pectorals and the number of abdominal vertebrae, but as the different species have the same number, I need not refer further to them here. I have also counted the number of scales along the lateral line in a number of specimens, but will only mention the results under the diagnosis of each species. The principal numerical characters are the dorsal and anal fins and the caudal vertebrae. The following is a condensed summary of the results, the numbers in brackets indicating the probable range of variation, i. e. the limits between which over 70 % of the cases occur.

	D	A
a. *A. Grohmanni*		
14 postlarval spec..	73—79 (80)	51—57
b. *A. Thori* (=*A. Grohmanni* auct.)		
26 adult spec.....	84—(85—89)—91	63—(64—67)—69
28 postl. spec.....	84—(85—89)—92	63—(64—67)—69
c. *A. laterna*		
var. *macrostoma*		
9 adult spec.....	86—91	67—69
var. *microstoma*		
120 adult spec.....	82—(87—93)—94	63—(66—71)—74
135 postl. spec. [1]....	84—(87—93)—98	63—(66—71)—75
d. *A imperialis*		
72 adult spec.....	94—(96—101)—105	74—(76—80)—82
9 postl. spec.....	96—103	74—81
e. *A. Räppeli*		
9 postl. spec.....	110—116	86—94

[1] The Mediterranean specimens are not included here.

Taking a general view of the results first of all, it will be seen, that the genus *Arnoglossus* has a wide range of variation, in the dorsal fin from 73 to 116 rays, in the anal fin from 51 to 94 rays, i. e. 44 rays in each case, and in the caudal vertebrae from 23 to 35. Within these extreme limits the different species form an ascending series of links, each with exception of *A. laterna* with a restricted range of variation. Excluding that species, the extreme range of variation is about 10 rays for dorsal and anal fins and for the number of caudal vertebrae only 4; the probable range of variation, that is, within which over 70% of the occurrences lie, is usually only 5 rays and at most 2 vertebrae. It will be shown later, that the range of variation in *Bothus* is precisely the same.

Caudal vertebrae

	23	24		27	28	29	30	31	32	33	34	35
a. *A. Grohmanni*												
15 postl. spec.....	11	4										
b. *A. Thori*												
67 adult spec.....	..	..	..	3	43	21						
45 postl. —	..	..	..	6	19	18	2					
c. *A. laterna*				9	62	39	2					
var. *macrostoma*												
9 adult spec.	..	..	..	..	..	9	..					
var. *microstoma*												
120 adult spec.....	..	..	..	1	11	57	44	7				
271 postl. [1]	..	..	..	1	35	132	69	31	3			
				2	46	189	113	38	3			
d. *A. imperialis*												
74 adult spec.....	..	..	..	..	..	..	..	..	15	48	10	1
13 postl.....	..	..	..	..	..	..	..	..	1	12		
									16	60	10	1
e. *A. Räppeli*												
9 postl. spec.....	..	..	..	..	..	..	..	..	..	1	6	2

[1] The postlarval specimens taken by the "Thor" in 1908-10 are not included here. The postlarval specimens referred to were taken by the "Thor" in earlier years, in the North Sea, Channel and Bay of Biscay, and include PETERSEN's "*A. Grohmanni*".

It seems reasonable to conclude, therefore, that the variation shown by *A. laterna* is improbable and that 2 species at least may be included thereunder, for not only is the total range of variation very

much greater than for the other species (13—15 rays and 6 vertebrae), but even the probable range is abnormally great. It should be noticed, however, that the large-mouthed variety (*macrostoma*) is not distinguished from the small-mouthed variety by these numerical characters. Hence, if the number of fin-rays and vertebrae suggest, that 2 or more species are included here under *A. laterna*, these species must be of the small-mouthed type and it is thus a question, not merely of 2 species (*macrostoma* and *microstoma*) but of 3 or 4.

As we are only dealing at present with general considerations bearing on the possibility of defining and delimiting the specific characters within the genus *Arnoglossus*, this interesting problem of the compound nature of *A. laterna* may be postponed until all sides of the matter have been considered (see under *A. laterna*). Meantime, it is worth while enquiring, whether we know any parallel case to *A. laterna* among other groups of flat-fishes.

The question of the possible and probable limits of variation in the numerical characters of flat-fishes has not yet been investigated, but Duncker (1900) has found the following in 1120 specimens of *P. flesus* from Plymouth: D 55—71; A 38—48, with a probable range of 4—5 and I may give here some hitherto unpublished data regarding the plaice (*P. platessa*), which bear upon this question and furnish a good parallel with *A. laterna*.

It is evident from the data, that the plaice of the North Sea region alone show a greater range of variation in the number of fin-rays than even *A. laterna* taken in the widest sense and if we take the Baltic plaice into account the number of caudal vertebrae vary to the same extent as in *A. laterna*. It may yet be found also, that the Icelandic plaice and the plaice of the Murman Sea give an even greater range of variation for the plaice as a whole.

P. platessa L.

a. North Sea; 929 specimens.

D.	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82
	4	5	5	19	26	51	116	127	141	115	115	72	56	41	25	8	1	1	1

A.	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
	1	3	11	31	57	112	183	164	158	112	63	23	9	1	1

Caudal vert.	28	29	30	31	32
	2	110	647	169	1

b. Baltic; 47 specimens.

D.	62	63	64	65	66	67	68	69	70	71	72	73
	1	1	7	4	6	6	5	7	5	2	2	1

A.	46	47	48	49	50	51	52	53	54
	2	4	6	13	5	10	3	3	1

Caudal vert.	27	28	29	30	31
	1	3	22	15	16

This comparison enables us to view the data with regard to *Arnoglossus* in a totally different perspective. Whereas examination of the data for the different species of *Arnoglossus* would lead a statistician to say at once, that *A. laterna* must contain several species, the example given by the plaice of the possible variation in a flat-fish would induce him to form a more reserved judgment. There is in reality nothing improbable in the fact, that *A. laterna* seems to have a much greater variability than the other species of *Arnoglossus*. These other species, *A. Grohmanni, A. Thori* and *A. imperialis* at any rate, have a more restricted distribution or live under more uniform conditions than *A. laterna*, which, as will be shown, ranges from the Kattegat and Norwegian coasts to the easternmost parts of the Mediterranean. The different localities or areas of distribution may have just as much effect, perhaps more, in forming local races of *A. laterna* as in the case of *P. platessa*. On the other hand, this statement is not to be taken as a final judgment on the matter. We have still to review the evidence offered by the postlarval characteristics.

Summing up with regard to the numerical characters, we may say, that whilst these have as a rule a restricted range of variation and form important specific characters (*A. Grohmanni, A. imperialis* and *A. Rüppeli*), yet they are not infallible. On the one hand, 2 distinct species have the same number of fin-rays and vertebrae and are thus indistinguishable by means of the numerical characters (*A. Thori* and

A. laterna). On the other hand, the general rule of a restricted range of variation in number of fin-rays and vertebrae is broken in the case of *A. laterna*, which apparently contains, therefore, either a number of different species or a number of varieties and races. The importance or weight to be attached to the variability of *A. laterna* depends naturally in the first place, on the amount of support other characters give to the differences in the numerical characters; in the second place, it also depends on the inherent probability or improbability of such a wide range of variation within one single species. With regard to the latter point, the plaice (*P. platessa*) has furnished an example of an equally wide range of variation in numerical characters. And with regard to the first point, the subdivision of *A. laterna* according to dimensional characters into var. *macrostoma* and *microstoma* is not supported by the numerical characters (at least not in the available material), whilst, so far as we have gone, there are no structural or dimensional characters which support the difference in the numerical characters. It now remains to see, whether the differences in the numerical characters are correlated with distinct and well-marked differences in the postlarval characteristics.

(4). Postlarval characteristics of the genus *Arnoglossus*. During postlarval development, from the time when the yolk of the egg has been absorbed until the adult characters are assumed, all species of flat-fish pass through various phases and possess certain characteristics, which are as distinctive of each group and each genus as the adult characteristics themselves. They are thus most valuable specific characters and they can also be used most effectively in the estimation of mutual affinities. A striking example of this is found in the relationship of the two genera *Arnoglossus* and *Bothus*. Although these two have sometimes been placed together under one genus, the affinity is not very obvious from the adult characteristics. The postlarval characteristics show, however, that these two genera are more nearly related to one another than to the other genera of the family *Rhombidae*.

For the sake of convenience, we may subdivide the postlarval characteristics into two categories; the permanent and temporary. The former appear in the postlarval phase and are retained permanently in the adults, as, for example, the migration of the eye, growth of the ventral and caudal fins, enclosure of the abdomen and so on. In each of these characters the different species show the type of the genus, or it may be larger group, and the main specific differences lie in the time (as judged by length) for the appearance and development of the permanent character. The characteristics of the second kind are purely temporary organs, arising during postlarval life and disappearing when metamorphosis is complete or even before; air-bladder, postlarval teeth, tentacles and especially the pigmentation and spines are of this category. It is a curious thing, that the *Pleuronectes* and *Solea* groups of flat-fishes show little or no sign of temporary characteristics in the postlarval stages, whilst in other groups (*Rhombus, Bothus, Symphurus*) temporary, postlarval characteristics are developed to a remarkable extent.

There is no genus of flat-fishes, yet known, in which the postlarval characteristics are so remarkable or so diverse as in *Arnoglossus*, though other genera may have a stranger postlarval history (e. g. *Symphurus*). Some of these characteristics are shared in common with *Bothus* and reference will in so far also be made to this genus here.

With regard to the manner in which the different species of *Arnoglossus* have been identified in the postlarval stages, it may suffice for the present to recall the results of the preceding section. With exception of *A. Thori* (= *A. Grohmanni* auct.) and *A. laterna*, the different species are readily distinguished in the first instance by means of the numerical characters (see p. 34); this becomes less necessary, however, when the other postlarval characteristics are known, as these are so very distinctive. On the other hand, Ehrenbaum's description of the postlarval development of *A. laterna* from the North Sea (1897) has enabled the postlarval specimens of this species to be distinguished from those of *A. Thori*, which also has very different postlarval characteristics.

Dorsal tentacle. One of the most remarkable characteristics of *Arnoglossus* in the postlarval

stages is the long appendage or tentacle attached to the head. This appendage is not peculiar to *Arnoglossus*, however, it is also present in the earlier stages of *Bothus* and is most conspicuous in a very large form, over 50 mm. in length though still symmetrical, from the Mid-Atlantic. It will probably prove to be present in a number of genera from subtemperate and tropical regions.

This tentacle is not a gradual growth from the head but appears to be formed, full-grown so to speak, from the upper margin of the embryonic fin. It is not present in the larval stages, and its sudden appearance thereafter, long before the fin-rays develop, suggests, that it arises from the longitudinal splitting of the outer edge of the dorsal fin, from in front to some distance behind the anus. Its structure and subsequent development are in complete accordance with this explanation, which was first put forward by Ehrenbaum (1897). "Es scheint nämlich — und besonders die Verteilung des Pigments in dem Geisselanhang bietet hierfür einen Anhalt — dass der Anhang sich aus dem vordersten Teil der embryonalen Rückenflosse herausschält, von der er ursprünglich einen integrierenden Teil bildet." In the earliest stages in my possession the natural position of the tentacle appears to be along the margin of the dorsal fin. With the growth of the fish, the base of the tentacle turns through an angle away from the fin, with the result that the tentacle becomes more and more vertical and in the later stages, especially in the species with prolonged postlarval development, it may even have a horizontal position, projecting out in front of the fish. As a matter of fact, however, the movable articulation of the tentacle to its base permits it to take up any position over an angle of about 120° from the horizontal, starting from in front of the head.

The tentacle also reveals its origin when injured, as is usually the case. It is then seen to be composed of two longitudinal halves of the primary fin, which is double not single. The true fin-rays which are formed later in the primary fin are also double in the same way. Further, it is not merely the extreme edge of the fin which separates off and goes to form the tentacle; an underlying portion of the fin also comes away with it and this portion contains in all species a considerable amount of pigment-cells, either massed in one or two groups or scattered along the tentacle. In preserved material, however, the fringe of the tentacle is always more or less crumpled up or entirely absent, so that beyond being able to state that the pigment is present in all cases, I cannot say whether its distribution on the tentacle is of specific importance or corresponds with the suggestion of Ehrenbaum quoted above.

As soon as the tentacle is separated from the fin, that is in the earliest stages in my possession, it is seen to be differentiated into two parts, a long, whip-like rod which lies along the anterior margin and a much broader piece of fin-membrane behind. Already at this stage staining with alizarine shows that the rod has a bony casing and it is evident also, that unlike the fin-rays the ossification has proceeded directly in the membrane without previous formation of cartilage. When an aniline stain is used, on the other hand, the rod remains undifferentiated from the membrane, whilst the cartilage at its base is distinctly coloured.

In the beginning the bony rod within the tentacle is not jointed, at least I have not been able to determine the presence of joints with certainty, but it very soon becomes divided into a number of articulations. In my largest postlarval specimen of *A. Rüppeli* I have counted up to 5 joints and in the large specimen from Mid-Atlantic there are 8—10 joints. This structure clearly adds to the flexibility of the tentacle. The length and breadth of the tentacle have been measured in a number of specimens and it is evident, that in some species at any rate the tentacle continues to grow during postlarval development. In the smallest species, *A. Grohmanni* (Bonaparte), it is 2.25 mm. long at 7 mm. total length and does not exceed 3 mm. in the largest specimen. In *A. Thori*, *A. laterna* and *A. imperialis* it is 3 mm. long in the smallest specimens (6—9 mm.) and grows to 4 and 4.25 mm. The growth in these species is not

conspicuous. In A. Rüppeli, on the other hand, the growth is considerable, as the following series of measurements shows; at 6 mm. length of tentacle 3 mm.

9 —	4 —
12.5 —	5.5 —
15 —	6 —
26 —	6 — (tip broken)

As the different species have all been caught and treated in the same way, it seems to me, that the greater length of the tentacle in *A. Rüppeli* is connected not only with a longer postlarval period but also with a habitat over deeper water. In the large postlarval specimen from Mid-Atlantic the tentacle has a length of ca. 22 mm. In *Bothus*, on the other hand, it is always quite short, ca. 3 mm., and soon disappears (text-figs. 13—17).

The breadth of the bony rod in the tentacle is, to begin with, about 0.02 mm. and also increases though slightly during postlarval development. In the largest postlarval specimen of *A. Rüppeli* the breadth is 0.05 mm. In all cases the breadth was measured just above the expanded base.

In the later postlarval stages of all species of *Arnoglossus* and *Bothus*, it is found that the tentacle is in reality a prolongation of the 2nd dorsal ray, not the first. When metamorphosis is about halfway complete, namely, a small ray appears in front of the tentacle, arising from the anterior prominence of the same large interspinal bone that supports the tentacle. This first ray is very short and not pigmented, and in consequence not readily seen. As a rule it is inclined backwards behind the base of the tentacle and is thus most easily found, especially when stained, on the right or future blind side of the fish. When metamorphosis is complete, this first ray is found to lie not on the ridge of the head but well down on the side and close to the posterior nostril of the blind side.

The most remarkable thing about this tentacle is perhaps its disappearance. Raffaele (1888, pp. 51, 52) thought that in the form called by him *A. Grohmanni* (= *A. Thori*) the tentacle persisted to form the characteristic, elongated 2nd dorsal ray of the adult. But this is not quite the case; as a general rule the tentacle entirely disappears in all the forms. Except in the case of *A. Grohmanni* (Bonaparte) my material is quite convincing on this point. I have seen only 2 specimens of *A. Thori*, which suggest that the postlarval tentacle may sometimes become the elongated 2nd dorsal ray (see later, under *A. Thori*). When metamorphosis is completed in all species, the tentacle as such is not to be found, nor have I been able to detect any difference between the length of the first few dorsal rays and that of the others. The elongation of the rays in "*lophotes*" (*A. imperialis*), like the prolonged 2nd dorsal ray in "*Grohmanni*" (*A. Thori*) is therefore a later growth. The gradual growth of the filamentous attachment of the 2nd dorsal ray in the latter species after metamorphosis can also be followed a little way in my specimens. So far as I have been able to determine, the disappearance of the tentacle does not mean that the whole of it is thrown off, it seems rather to be broken off at a short distance from the base and the stump remains as the base of the 2nd dorsal ray of the adult. There can hardly be any talk of reabsorption here, as the tentacle suddenly disappears just at the period when the eye is migrating (in *Arnoglossus*). I have no metamorphosed stages of *Grohmanni* (Bonaparte), and cannot say with certainty how much of the tentacle stump remains in this case, but it is worth mentioning that in Bonaparte's figure the 2nd dorsal ray has much more the appearance of the stump of a tentacle, such as one finds in the late postlarvae, than of the pennate appendage characteristic of the species *A. Thori*, which has so long been called *A. Grohmanni*.

In *Arnoglossus* the disappearance of the tentacle is one of the changes in body and head which occur during the migration of the eye. In *Bothus*, on the other hand, the tentacle disappears very early during postlarval development, after which and during the rest of a very prolonged, postlarval life, this species (and probably genus, see later) is able to do without such an organ. In *Rhombus*, again, and especially in the whole family *Pleuronectes* there is no trace at all of a tentacle.

Its function seems rather a puzzle, therefore; but if we leave aside the question, why it is absent in *Pleuronectes* and *Rhombus*, I think that we can understand its presence in *Arnoglossus* from its presence and absence in *Bothus*. Comparison of the postlarval stages in the two forms gives, in fact, a very clear solution to this side of the problem. In the early stages both forms are in so far alike that the front part of the cranium is quite unprotected and the tentacle is present. If these forms are able to swim comparatively swiftly, it is probable that the tentacle projecting in front and above is able to give notice of impending danger. In *Bothus*, however, the front interspinal cartilages of the dorsal fin very early grow down and become permanently attached to the ethmoid in front of the eyes (text-figs. 13—17) and the bridge thus formed between the ethmoid region and the occiput will act as a spring to dissipate the effect of pressure or a sudden blow. When this bridge is formed, the tentacle is thrown off; there is in fact no further need or use for it. In *Arnoglossus*, on the other hand, the whole of the postlarval life is nearly completed before the bridge mentioned comes to rest on the nasal cartilages and the resting is in this case not the same as attachment, for the whole anterior, overhanging part of the dorsal fin breaks loose at this moment from the frontal region to let the eye swing round to its permanent position and then, and not till then, the bridge becomes attached obliquely on the blind side of the ethmoid region. Thus, the bridge of interspinal cartilages in the later, postlarval stages of *Bothus* takes the place of the tentacle in *Arnoglossus;* their function is not precisely the same, the former acts directly as a protection, the latter more to give warning, but they serve the same purpose in the end, namely, to guard against damage to the front part of the brain-case. In *Rhombus* and the other genera which have no tentacle, there may be several reasons for its absence; the postlarval life may be very short by comparison with that of *Arnoglossus* and *Bothus* or the larvae may move comparatively slowly; in any case, the protection to the front part of the brain is not required to the same extent or is provided in another way.

In Arnoglossus, as mentioned, the disappearance of the tentacle is contemporaneous with the migration of the eye, and thus takes place at a different length in the different species. We do not require to use it as a distinguishing character, however, since the time or length at which metamorphosis is complete is practically the same and is a more conspicuous character.

Ventral fins and pubic bones. Whilst the pectoral fin of the larval and postlarval stages is a well-developed, temporary organ, which is present in the earliest stages and undergoes transformation to become the permanent pectoral fin of the adult after metamorphosis is complete, the ventral fin only arises later and gradually assumes its permanent form and position during postlarval development itself. When the larva escapes from the egg, the temporary pectoral fin is already fully formed, but there is no trace of the ventral fin; even the rudiment of the pubic bone is not present. All that can be seen (figs. 5, 6) is a long straight, cartilaginous rod extending backwards from the base of the clavicles ventral to the liver as far as the abdomen. The presence and position of this cartilaginous rod may have some phylogenetic significance.

As development proceeds, the anterior part of this cartilaginous rod or bar becomes bent upwards just behind the clavicles, and between it and the clavicles there is a concentration and thickening of tissue which gradually forms a small, opaque bud, the rudiment of the ventral fins (text-fig. 3, I). A little later this bud assumes a definite, triangular form with the apex close to the base of the clavicles and the base fused to the cartilaginous rod. At the same time the permanent rays are laid down but do not yet penetrate to the surface (text-fig. 3, II). This stage in which the whole of the apparatus of the ventral fins is still behind the clavicles, is well-marked and corresponds approximately to half way through postlarval development.

In the next stage there is a remarkable change in the course of development of the ventral fins. The clavicles retire from the ventral margin or more correctly, the ventral margin grows down from the clavicles, leaving a space for the growth of the left pubic bone forward, or rather, the anterior cartilaginous plate attached to the pubic. In this stage also the first 3 rays of the left ventral project beyond the skin.

The growth forward of the left pubic is very gradual and postlarval development is nearly completed before it has reached its permanent position, well in advance of the clavicles and attached to the lower prong of the urohyal below the gill-cover. The right pubic never reaches beyond the base of the clavicles and its 6 rays correspond in position to the last 3 rays of the left pubic.

Various stages in the development of the ventral fins are shown in the accompanying text-figures, and each stage is given a definite number for convenience. The first (0) stage, in which there is nothing but the horizontal bar and the 5th stage, in which the left ventral is prolonged still further forward under the interoperculum, are not represented. The Table below shows the lengths at which the different species reach the various stages. *Bothus podas*, which also passes through the same stages, is included for the sake of comparison.

Fig. 3. Development of the ventral fins and their position relative to the base of the clavicles in the genera *Arnoglossus* and *Bothus* Stages I and II magnified 30 times, Stage III 25 times and Stage IV 10 times.

	Stage I	Stage II	Stage III	Stage IV	Stage V
A. Grohmanni	7 mm.	10 mm.	11 mm.	12 mm.	
A. Thori	8—9 —	10 —	12 —	16 —	20 mm.
A. laterna	8—9 —	10—11 —	12—13 —	15—18 —	18—24 —
A. imperialis	9 —	11 —	14 —	18—20 —	ca. 30 —
A. Rüppeli	9 —	12 —	15 —	25—28 —	30 —
B. podas	8—9 —	11—12 —	14 —	18—20 —	24 —

With regard to the cartilaginous pubic bar, it will be noticed from the figures on the Plates, that this extends along the ventral margin beneath the liver. In *Arnoglossus* it reaches just to the ascending part of the intestine; in *Bothus* it extends even further, as the lower portion of the intestine rests upon it. In the large Atlantic form (text-figure 26), the cartilaginous bar is very long, as in *Bothus*. It need hardly be said, of course, that this bar is really double, i. e. one to each pubic bone.

When metamorphosis occurs and the abdomen becomes enclosed below by the approximation of the anal fin to the ventral fins, the long posterior portion of the cartilaginous pubic bar disappears, probably through reabsorption. A stump remains, however, on each just behind the pubic bone, forming a sharp point or spine ventrally, with the spine of the left side lying a little in front of that of the right side. In the adults when damaged or badly preserved, these spines may project through the skin ventrally between the two ventral fins and this condition is usually represented as the normal in the published figures of *A. laterna*. As with the anal spine in *Pleuronectes*, however, these spines do not project through the skin in normal specimens, though one can easily feel them under the skin.

The caudal fin and ural elements develop just as in the better known flat-fishes. By the time the dorsal and anal fins are fully formed, the end of the notochord has gone through the various well-known phases and become completely enclosed by the upper, epiural element. There are as usual 4 ural elements, the two broad central elements, usually called hypurals, the wedge-shaped epiural above and a corresponding hypural below. The two latter become fused to the neural and haemal spines respectively of the 2nd last vertebra — and these spines also take part in supporting the caudal rays, the one above, the other below — whilst the two central hypurals become more or less fused together and with the base of the end of the notochord, thus forming the last vertebra. The length of time at which the

dorsal, anal and caudal fins are fully formed varies a little naturally in the different species (cf. figures of Plates), but the process of growth is much more rapid than in the case of the ventral fins and we thus do not find here such a good distinguishing character as in the case of the ventral fins. The accompanying figures show the different stages in development.

Spinulation. With one exception all known genera of the family *Rhombidae* have spines in one form or another in the postlarval stages, but none have such a well-developed system of spines as we find in Arnoglossus. Petersen (1909) and Williamson (1911) have mentioned the presence of a few spines in *Arnoglossus*, the former in the so-called *A. Grohmanni*, the latter in a specimen, which he was unable to identify but which was probably *A. laterna*. But the development of spines is very much greater than was remarked by these authors[1] and forms one of the most valuable characters in the separation of the

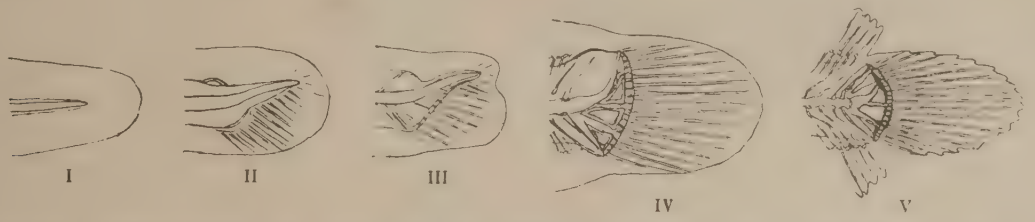


Figure 4. Different stages in the development of the caudal fin and ural elements in *Arnoglossus* and *Bothus*. I & II × 25; III & IV × 20; V × 10.

different species. As metamorphosis approaches, the spines gradually disappear, either becoming the ciliation of the scale or through being thrown off, which seems to be the rule. Thus, the spines are purely postlarval structures, the significance of which is hard to guess. There is no vestige of a spine in *Bothus podas*, in which as is well-known the permanent scales are somewhat densely ciliated, and in the smallest species of *Arnoglossus* (*A. Grohmanni* Bp.) it is doubtful whether spines are present or not. But it should be remarked, that the postlarval teeth in all these forms, including *Bothus*, are of the same nature and structure as the spines, and are thrown off as metamorphosis approaches.

The different degrees in the development of the spines are shown in the accompanying text-figure 5. The very earliest stage is that seen in 1 a, where we have but a small wart or tubercle on the surface of the skin. When stained with alizarine it appears as a shining nodule in the skin with the point projecting outwards. Its resemblance to the first beginnings of a tooth is obvious. *A. Grohmanni* never seems to grow spines beyond this stage and even these must be very few; at least, I have only succeeded in discovering one single doubtful nodule at the base of the tentacle in a specimen 12 mm. long.

The development from the nodule to the full-grown spine and further is shown by the various stages represented in the figures. The point of the spine grows outwards and the base develops three prongs, which hold the spine fixed in the skin. The next stage in development is the formation of an aggregate of several spines, that is, where the single spines grow in close proximity to one another and their bases, if not quite fusing, yet form a concrete mass which has the appearance of a plate though without definite margin. This stage is represented in 2. This seems to be the highest stage of development reached in *A. laterna*. In this species we find mostly single spines, but along the margins of the interspinal regions and particularly at the base of the first 3 or 4 dorsal fin-rays the spines form an

[1] It should be mentioned, that Schiödte (1868) found these spines in his mysterious *Bascanius tædifer*. "The whole fish is fairly densely strewn with small warts, which on the head have no definite order, but on the greater part of the body, on the interspinous portion of the dorsal and anal fins and on the root of the tail are arranged in longitudinal rows. These warts are almost round, ca. 0.1 mm. in diameter, very flatly arched and armed with some few, very small and short spines; only along the outer margin of the interspinous region of the dorsal and anal fins and on the root of the caudal the warts are more arched, almost semispherical and with several and longer spines." It will be seen, that this description agrees fairly well with what is found in *A. Rüppeli* (Cocco), and the description otherwise of the fish agrees well with this species.

aggregate as represented. These aggregates were taken by Ehrenbaum (1897) to be spots of pigment. In the later postlarval stages of *A. laterna*, from 18 to 20 mm., it can be seen how these single spines may persist to form the ciliation of the permanent scales (3, 4, 5 and 6). Small scales with a single spine attached and without rings (as shown in 3) are very common at the size mentioned; the membrane of the scale, to one end of which the prongs of the spine are fused, serves as a wider base of attachment for the spine. Simple scales with 2 spines attached are also frequent, but the commonest are those with 3 spines; more than 3 I have not seen at the size mentioned. The scales on the body of the fish have as yet no spines (7).

Fig. 5.

Spinulation in postlarval *Arnoglossus*. 1, Development of the single spine. 2, Aggregate of single spines without definite boundary (*A. laterna*). 3, 4, 5, 6, Occasional conversion of postlarval spines to ciliation of adult scale. 7, Ordinary, smooth scale. 8, 9, 10, spined plates (*A. Thori, A. imperialis* and *A. Rüppeli*). 11, Spines on cartilaginous pubic bar in *A. imperialis*. 1—10 magnified ca. 1500 times. 11, ca. 50 times.

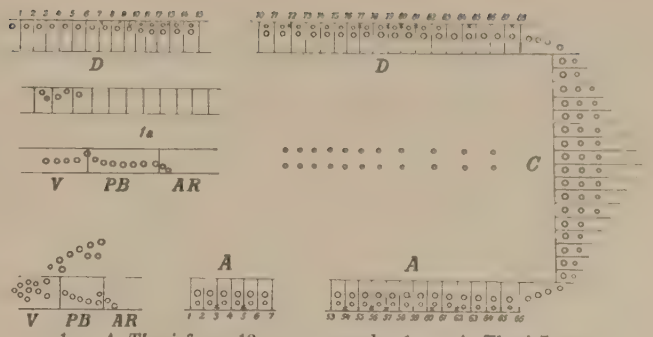
In the remaining species of *Arnoglossus, A. Thori, A. imperialis* and *A. Rüppeli,* we have a totally different condition of things. In these, even in the earliest stages of 7—10 mm., the spines have past beyond the aggregate stage and form definite plates with definite margins (fig. 10 for the earliest stage); single spines are also present but greatly in the minority. Halfway through postlarval development these plates with spines, which we may simply call spined plates, are very prominent objects in the species mentioned especially after staining. Their greatest development is reached in *A. imperialis* and *A. Rüppeli* and they may bear up to 9 spines.

The distribution of the spines and spined plates on the body of the postlarvae is also remarkable and characteristic for the different species. Whilst in the other genera of *Rhombidae* the spines, so far as yet known, only occur about the head region, that is on the skull, gill-cover, and pectoral arch, in *Arnoglossus* there are no spines on the head at all; we find them all round the margin of the interspinal regions, on the caudal fin and on the abdomen and base of the ventral fin. Their distribution is shown in several specimens of each species on the Plates, but it will perhaps be more readily grasped from the accompanying diagrams.

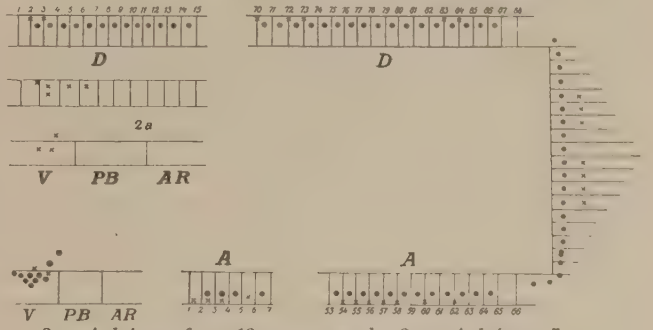
The most remarkable thing about the distribution of the spines is perhaps their presence on the abdominal region. In the smallest form (*A. Grohmanni*) there is no trace of spines here; in *A. laterna* the only spines in this region are to be found on the base of the ventral fins, and one aggregate on the inner side of the cartilaginous bar above the margin of the liver; there is no sign of spines anywhere else on the abdominal region in these species. In the remaining 3 species, *A. Thori* (*A. Grohmanni* auctorum), *A. imperialis* and *A. Rüppeli*, there is a rich development of spined plates over the lower half of the abdominal region, but not to the same extent in the different species. *A. Thori* has the smallest number of spined plates here; there is a row of 5 to 6 spined plates on the cartilaginous pubic bar, and an oblique row of 5 to 6 across the liver from the base of the ventrals with signs of a second row; further, a plate sometimes appears on each side of the abdominal coil, but I am not sure how far this may be accidental (see below). In *A. imperialis* the distribution is the same as in *Thori*, but there are many more plates on the cartilaginous pubic bar and 3 rows across the liver, besides one or two plates on each side of the intestine; there are none on the rectum. In *A. Rüppeli* lastly there is no sign of a plate on the pubic bar, the rows on the liver are less conspicuous, but there is a large collection of plates about the rectum posteriorly and along the 1st interspinal bone.

A second remarkable thing about the spines is their very early appearance. The rudiments of the spined plates on the pubic bar in *A. Thori* and *A. imperialis* can already be seen distinctly at 7 mm. and the single spines above the head are probably developed in all species (except *Grohmanni*) at an earlier stage. The spines along the margins of the interspinous regions develop pari passu with the development of these regions, which takes place between 9 and 12 mm.

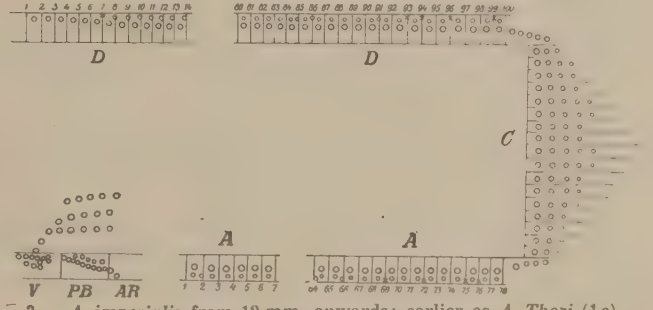
The third remarkable point is the dis-



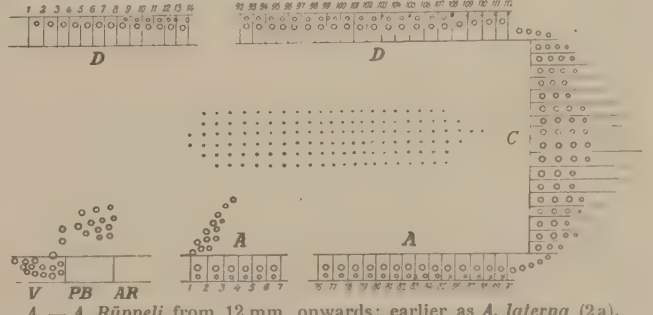
1. — *A. Thori* from 12 mm. onwards; 1 a — *A. Thori* 7 mm.



2. — *A. laterna* from 12 mm. onwards; 2 a — *A. laterna* 7 mm.



3. — *A. imperialis* from 12 mm. onwards; earlier as *A. Thori* (1 a).



4. — *A. Rüppeli* from 12 mm. onwards; earlier as *A. laterna* (2 a).
For the rest, see text.

Figure 6.

Distribution of the spines in the different species of *Arnoglossus*. D — dorsal fin; C — caudal fin; A — anal fin; V — ventral fin; PB — cartilaginous pubic bar; AR — abdominal region. A simple cross stands for a single spine, a black spot for an aggregate of spines and a circle for a spined plate.

appearance of the spines. These are most conspicuous about half to two-thirds of the way through postlarval development and it is these stages which should be taken to find their extreme or typical development. Even before the changes incident to metamorphosis set in, the spines appear to become reduced both in size and number. Their reduction may thus be taken as a sign of incipient metamorphosis; for example, in a specimen of *A. imperialis* of 29 mm. in length the spines have almost entirely disappeared, whereas in specimens of 18 or 22 mm. they are large and prominent. It seems to me that the disappearance of the spines is for the most part due simply to their being thrown or rubbed off, though resorption may also take place to some extent. As the spines and spined plates are purely skin-structures, it can be readily understood why and how they should disappear, when the changes occur in the skin preparatory to the formation of the true scales. But the spined plates, especially in *A. Thori*, are frequently rubbed off at a much earlier stage, during the preservation and mounting of the specimen or even, and more probably, during capture. Thus, the plates may be found lying loose on the slide or on various parts of the body, e. g. over the swim-bladder. The general scheme which I have given above is based on the examination of a large number of specimens and represents, I believe, the typical distribution in each species.

A further point to be noticed in connection with the distribution of the spines, is that rows of single spines appear on the body in the caudal region as metamorphosis approaches in several species. Thus, in *A. Thori* there are two or three rows of these single spines above and below the vertebral column from the abdominal region back towards the tail. But their greatest development is seen in *A. Rüppeli*, where there are 3 rows along the vertebral column and 4 to 5 above and below, in a specimen about 29 mm. in length.

It will be seen from the above description, that the system of spines serves as a most useful aid in the identification of the species. When spines are present on the cartilaginous pubic bar, the specimen can only be one of two species, *A. Thori* or *A. imperialis;* if in addition, they are well-developed and conspicuous on the liver and ascending and descending coil of the intestine, then the specimen is almost certainly *A. imperialis*, which for the rest is readily distinguished from *A. Thori* by other characters. It has to be remembered, however, that the spined plates are liable to be rubbed off, especially in *A. Thori*, so that their absence in whole or in part is not to be taken as an infallible sign, that the specimen does not belong to one or other of the species mentioned. Again, the presence of a large collection about the rectum and first interspinal is a certain indication, that the specimen belongs to *A. Rüppeli*. *A. laterna* can thus be readily distinguished from the above-mentioned species by means of the spines alone, though the separation of the different forms of *A. laterna* is a more difficult manner, to be discussed later. Lastly, *A. Grohmanni* does not appear to have any spines at all, but in this species we do not require to use this character.

Postlarval teeth. As already mentioned, the postlarval stages of *B. podas* have no spines on the body or head, but they agree with the *Arnoglossus* species in having postlarval teeth, which differ from the spines on the body only in being larger and thicker. In size, they are of course not to be compared with the postlarval teeth of the *Leptocephali*, but like them they are comparatively few in number, are sharply pointed and separate from one another, whereas the adult teeth are more wedge-shaped, numerous and close together. So far as I am aware, no suggestion has ever been made, that the teeth in the postlarval forms of flat-fishes were purely transient organs, and I am unable at the present moment to speak for the other genera, but there can be no doubt about the fact in *Arnoglossus* and *Bothus*. The evidence is briefly as follows; (1) the postlarval teeth have a different shape and arrangement from those of the adult; (2) the postlarval teeth are deciduous and disappear towards the approach of metamorphosis, the larger specimens having only one or two teeth and frequently, especially in *Bothus*, none at all; (3) the roots of the adult teeth only appear during metamorphosis, and the postlarval teeth or the last of

them may still be present to show their distinctness from the adult teeth. The postlarval teeth which persist the longest are the two on the extreme points of the intermaxillaries. In the early stages the postlarval teeth stand out clear and naked to the base, just like spines, whereas the adult teeth are surrounded by skin at their base ("en velour").

Pigmentation. The pigmentation in postlarval fishes is as a rule of specific value, but it is equally a rule that the pigmentation, especially in preserved specimens, must be treated with caution. In *Arnoglossus* (*Bothus* will be dealt with separately) the postlarval form is true to both rules. When typically developed, the pigmentation is in itself quite sufficient (except in the case of the two species *A. Thori* and *A. imperialis*) for the identification of the different species, but when the pigment is defective through preservation or other cause a certain identification from the pigmentation alone may be impossible.

We can distinguish between three stages in the pigmentation; the larval, early postlarval and late postlarval. The first stage is naturally not represented in my material, but it has been well-described for at least two if not three species of *Arnoglossus* by Ehrenbaum and Holt. In the larva of *A. laterna* and *A. Thori* (called *Grohmanni*) the pigment is distributed in two main zones with additional clusters of chromatophores elsewhere. The principal zone lies across the body and marginal fins about halfway between the anus and the end of the notochord; this may be called the postanal bar. The second main zone lies across the body from the anus to the dorsal marginal fin, but it is not continuous; the principal part lies on the swim-bladder, a few chromatophores are present about the rectum and anus and on the dorsal side there is a cluster of chromatophores on the embryonic fin. In front of the latter, towards the head, there are two or three more clusters of chromatophores on the body and later on the embryonic fin. So far there is no appreciable difference between the species, except that in *A. laterna* the predominant colour of the pigment is "braun-rot" (in the living specimens), where in *A. Thori* (called *A. Grohmanni*) it is more orange.

The above characteristics can still be traced in the early postlarval stages, but it should be noticed that preservation makes a great difference on the pigmentation. In the first place, the coloured pigment either disappears entirely or is altered in tint. Where it persists, a distinct difference can be seen between the species mentioned. In *A. Thori* the colour is rusty brown or orange-brown, and this is also the case in *A. imperialis*, whilst in *A. laterna* it becomes usually a pale yellow. This difference is most marked as a rule in the pigment on the swim-bladder. Secondly, the embryonic fin is usually more or less torn in preserved specimens, and it is only occasionally that one can discover the marginal pigment on it. But, so far as my observations go, this marginal pigment on the fins is more marked in *A. Grohmanni* (Bonaparte nec auctorum) and *A. laterna* than in the other species, that is, in the early postlarval stages. In the following description, however, I leave out of account the coloured pigment and the pigment on the margins of the embryonic fins.

If we could imagine an early postlarval specimen with a combination of the pigment found in all the species, that is, with the maximum amount of pigment, we should have the following picture. There would be a well-marked postanal bar on the body and what may be called a half bar on the air-bladder and down the rectum to the anus; dorsally there would be a row of small black dots along the margin of the body, a little later along the proximal margin of the interspinous region, reaching back to the postanal bar; ventrally there would be a similar row from the mandible in front along the margin of the gill-cover and abdominal region to the anus, then continuing along the margin of the body, a little later the proximal margin of the interspinal bones, as far as the postanal bar and then one or two dots between that and the beginning of the caudal fin, where there would be a conspicuous black patch of pigment; on the dorsal side of the notochord, opposite the last-mentioned patch there would also be a little black

pigment; lastly, there would be 2 or 3 spots anteriorly on the otocystic region. To obtain this picture, we may combine figs. 1, 5, 19, 21 of Plates I and II.

Starting from this picture, we see that the early postlarval stages of the genus *Arnoglossus* may be divided into two distinct groups. In the one group there is a tendency for the pigment to concentrate at the bars, anal half bar, postanal bar and notochordal bar. This group is represented by *A. Thori* (figs. 5—9), *A. imperialis* (figs. 22—26) and *A. Rüppeli* (figs. 27—31). In the other group the pigment at the bars is not so concentrated and tends on the whole to spread out along the margins of the body. In this group we have *A. Grohmanni* (figs. 1—4), and the various forms of *A. laterna* (figs. 13—21).

Within each group, again, there are certain well-marked differences. Thus, in the first, barred group we find that the notochordal bar is quite absent in *A. Rüppeli*, whilst in *A. imperialis* it is more above than below the tip of the notochord (fig. 22) and in *A. Thori* more below than above (fig. 5); this notochordal bar soon disappears, however, though a slight trace of it may sometimes still be seen at 11 mm. (fig. 24). Again, in this same group the postanal bar is not in the same position in the different species, nor does it change in the same way during the course of development. On counting the caudal vertebrae or myomeres, it is found that this bar lies on the 18—21st in *A. Thori*, on the 22—25th in *A. imperialis* and on the 23—26th in *A. Rüppeli;* further, in the last form the pigment from this bar spreads out ventrally on to the anal marginal fin at a very early stage (fig. 27). During the course of development, the postanal bar soon breaks up into two, the one half moving dorsally the other ventrally; in *A. Rüppeli*, however, the ventral portion remains the more developed, though the whole bar tends to be reduced to one or two chromatophores (figs. 28—31); in the other two species, *A. Thori* and *A. imperialis*, the two halves of the postanal bar remain the same size and also spread out equally on to the dorsal and anal fins. Further, when the postanal bar breaks up in these last two forms (about 8—10 mm.) the chromatophores also begin to appear along the base of the interspinal regions dorsally and ventrally; this is not the case in *A. Rüppeli*. Lastly, the anal half-bar is well-developed in this group, especially on the air-bladder, in the early stages; on the rectum and ventral to the intestine it is most developed in *A. imperialis*, moderately developed in *A. Thori* and not at all in *A. Rüppeli*.

In the later stages, *A. Thori* and *A. imperialis* can readily be distinguished from the other species even with the naked eye, owing to the presence of 2 black spots (one above and one below) on the caudal region. These spots come to lie distally on the interspinous regions and even more on the fins. These two species can be distinguished from one another by various characters, among others by the fact, that these postanal spots lie between D 60—67, A 50—57 in *A. Thori* and between D 75—81 and A 53—60 in *A. imperialis* with some variation, of course, on either side. It may be mentioned further, that the air-bladder in these two species usually remains a conspicuous object, well-pigmented, until close on metamorphosis, whereas in the other species it becomes small, with little pigment over it, at a much earlier stage.

In the second group, comprising *A. laterna* and *A. Grohmanni*, there appears to be an extremely wide range of variation. The characteristic of this group is, as already mentioned, that the pigment is very slightly concentrated into bars, after the interspinous regions are formed, but spreads out along the dorsal and ventral margins of the body. In both species, however, the extent to which this occurs, is exceedingly variable. Thus, *A. Grohmanni* may have a ventral row of small black spots right from the mandible to the anus and larger spots from there along the anal interspinous region to the tail, with a similar row dorsally; in other specimens, however, there are only a few chromatophores about the rectum and postanally (figs. 1—4). Similarly in *A. laterna*, there are all grades and transitions from practically no pigment at all to the greatest possible amount all round the body and head (comp. figs. 16 and 20). The extreme cases might well be considered to belong to separate species and it may be recalled, that Petersen (1909) referred the greatly pigmented form to the so-called *A. Grohmanni* (= *A. Thori*). This

greatly pigmented form has been found most abundantly in the Bay of Biscay, but it has also been taken along the western seaboard to Gibraltar and in the Mediterranean as far as the Dardanelles. In the north a few specimens have been taken in the North Sea and one even in the Kattegat. The pale form is by far the commoner in the North Sea and it is this form which has been described by Ehrenbaum in 1897. It should be expressly mentioned, that the distinction between pale and pigmented forms applies more particularly to the stages after the interspinal regions and vertical fins have been formed. Before this, naturally, it is more difficult to distinguish between the two. But it may be mentioned, that among some early stages kindly lent me by Prof. Ehrenbaum from Heligoland, the same variation could be seen, i. e. some had copious pigment, others practically none at all (cf. also Holt 1898, figs. 77 and 78). The Channel form again is intermediate though mostly with little pigment. In the Mediterranean both forms occur almost equally, with also some transitional stages difficult to refer to the one or the other. We thus have a somewhat complicated state of matters and it is only to a certain extent, that the dark and pale forms of *A. laterna* may be called geographical varieties; further, it has to be remembered, that the pigmentation in the allied form *A. Grohmanni* varies in the same way. Hence it is permissible to conclude, that the pigmentation in *Arnoglossus* may be exceedingly variable within one and the same species. The question whether this difference in pigment, associated with other differences, entitles these two forms of *A. laterna* to be regarded as distinct species, will be discussed under *A. laterna*, but meantime it may be mentioned, that in the main tables (pp. 16—21) I have distinguished between the specimens which belonged to the pale (A) and dark (B) forms of *A. laterna*. These pigment forms have naturally nothing to do with the question, whether the varieties *macrostoma* and *microstoma* of *A. laterna* are distinct species; that is quite a separate question, which will also be discussed later.

When metamorphosis is nearly completed, pigmentation makes its appearance in all species on the fins in the form of bars, 10—12 on the dorsal and 8—9 on the anal, and patches of small brownish dots gradually spread over the body and head (figs. 10, 11, 12). The 2 postlarval spots on the caudal region persist in *A. Thori* and *A. imperialis* and readily distinguish these from the other species, long after metamorphosis has been completed (cf. figs. 10, 11).

Metamorphosis. The metamorphosis of flat-fishes is usually associated with the migration of the eye from the one side of the head to the other. This is certainly the most prominent feature and the most convenient for reference, but metamorphosis really means much more; it means the decline or disappearance of the postlarval, temporary structures, teeth, spines, tentacle etc. and the final assumption of the adult form and characters. The successive changes in the different organs, e. g. growth of the permanent teeth, enclosure of the abdomen, scales and so on, are very useful in determining how near to or how far from metamorphosis a given specimen may be. In *Arnoglossus* and *Bothus* this is of special advantage, for the migration of the eye takes place very rapidly, the whole process being completed within the space of 1 to 3 days, thus presumably, whilst no increase in length is taking place[1]. This is very different from the condition in *Rhombus* and *Lepidorhombus*.

As can be seen from the figures, the growth forward of the tentacle and dorsal fin on to the ethmoid region in *Arnoglossus* and *Bothus*, leaves no opening or space for the migrating eye to pass from the one side to the other. This opening arises secondarily and in quite a different way in the two genera. In *Arnoglossus*, when the interorbital region bends to the left side, the front part of the dorsal fin becomes detached from the ethmoid and a slit is thus formed; the eye passes through this slit beneath the loose, overhanging, anterior part of the dorsal fin. Many specimens in my material are in this transient condition.

[1] There is even evidence to indicate, that the length may slightly decrease in *Arnoglossus* and *Bothus* on metamorphosis, and the breadth certainly decreases.

In *Bothus*, however, the anterior part of the dorsal fin does not become loosened from the ethmoid region, but an opening appears beneath the 5th to 11th interspinal cartilages and the eye slips through this opening. The changes in form and structure accompanying metamorphosis will be described elsewhere.

The stage or length at which the postlarval form assumes the principal adult characteristics is usually considered to be constant and definite, not perhaps to a mm., but such that if a variation of more than say 5 mm. occurred, we should be inclined to think that more than one species was present. A difference in the length on metamorphosis is thus as a rule a most valuable aid to the separation and identification of species, and all observers would probably agree, that if there is a difference of say 10 mm. between two series of specimens when metamorphosis takes place, though otherwise very similar, then the two series belong to different species. The validity of this rule varies inversely, however, with the absolute length. Thus, if one series metamorphoses at 10 mm., another at 20 mm., no one would doubt their specific distinctness however much alike the other characters were. The question here is, whether the same can be said for 20 mm. and 30 mm.

Before discussing this question, I may refer again to the species of the genus *Pleuronectes*, which may be cited for another reason, as they form an interesting parallel to what we find in *Arnoglossus*. In the four species of *Pleuronectes* in European waters (*P. limanda* belongs in reality to a different genus), we find that *P. flesus* metamorphoses about 10—12 mm., *P. platessa* about 14—16 mm., *P. microcephalus*[1] about 30 mm. and *P. cynoglossus* from 40—60 mm. In this case the prolongation of postlarval life varies directly with the transition from shallow to deep water and it is probable, that this rule may apply to groups or races of the same species which, on the approach of metamorphosis, are differently situated as regards depth of water.

With this introduction we may consider the condition of things found in *Arnoglossus*. We have here at least 5 different species and the lengths on metamorphosis (of formaline specimens) are the following:

A. Grohmanni (Bonap.) metamorphoses about	14 mm.
A. laterna sens. lat.	16—30 —
A. Thori (= *A. Grohmanni* auct.)	21—25 —
A. imperialis (Raf.)	30—(50) —
A. Rüppeli (Cocco)	40—(50)

With exception of the first, metamorphosed specimens of all these species are present in the collections made by the "Thor". Of *A. Thori* there are 3 specimens completely metamorphosed below 23 mm. and many postlarval specimens approaching metamorphosis between 18 and 21 mm. and one not metamorphosed at 24 mm.; all these specimens are from the Mediterranean. Of *A. imperialis* there is one specimen of 29.5 mm. which shows various signs of beginning metamorphosis, though the eyes are still symmetrical; another specimen of the same size is completely metamorphosed, whilst one of 35.5 mm. is still symmetrical and in 3 specimens of this species taken in the Atlantic (see later) 48 mm. had been reached in the postlarval stage. Lastly, there are 3 metamorphosed specimens of *A. Rüppeli;* one of 41 mm. has evidently just completed metamorphosis, a second is of the same size but has become clothed with scales and the third is 47 mm. in length but in a similar condition to the first (fig. 12, Pl. I).

The habitat of these different species will be discussed more fully later, but the main points of what we know may be mentioned here. *A. Grohmanni* appears to be a true shallow-water form, which seeks the bottom, like the plaice and other Pleuronectids, before metamorphosis is completed. *A. Thori*

[1] It would be of interest to discover, at what length the dwarf, Channel form of *P. microcephalus* metamorphoses. It may be recalled also, that the length on metamorphosis of *Drepanopsetta platessoides* varies greatly in different regions, from 24 mm. to about 40 mm. (PETERSEN 1904).

is also a shallow-water form, but metamorphoses pelagically. The adults of *A. imperialis* occur in 50—60 meters but may live in much deeper water. *A. Rüppeli* seems to be a true deep-water form.

The question is now, what are we to make of the great difference in length of the different forms of *A. laterna* on metamorphosis? It would seem quite contrary to our previous knowledge, to regard as belonging to one and the same species a large number of specimens which metamorphose at 16—18 mm. and another large number which metamorphose only at 26—30 mm. Here, however, we can distinguish between geographical forms. From the Southern North Sea (Holland) we have a large number of specimens (over 60) which show, that metamorphosis takes place there at a length of 16 mm. and even less. Specimens from the eastern end of the Channel also metamorphose about this length. At Heligoland *A. laterna* metamorphoses at 18—20 mm. (EHRENBAUM 1897), and off the Danish coast the length is the same. In the western end of the Channel, however, the length on metamorphosis is about 21 to 26 mm. (from an examination of over 60 specimens), the larger specimens over 24 mm. being predominant. Lastly, I have examined over 50 specimens from the Bay of Biscay, which clearly show, that metamorphosis occurs there mostly at lengths between 26 and 30 mm.

These geographical differences are so distinct, that the occurrence of abnormal specimens, e. g. a symmetrical specimen of 24 mm. off the Danish coast or a metamorphosed specimen of 21 mm. in Mounts Bay in the western Channel, at once strikes one as remarkable.

Viewed from the theoretical side, this case of extreme variation in *A. laterna* is not opposed to the parallel with the species of *Pleuronectes*. The length on metamorphosis of the different species of *Arnoglossus* increases with the transition from the shallow water to the deep water habitat. We have only to extend this rule to apply to different groups of the same species, which live in varying proximity to deep water. That is, within one and the same species it may be, that the length on metamorphosis increases with the transition from shallow to deep water. If there are more than one species under *A. laterna*, as understood here, where are we to draw the line of separation?

c. Summary of the adult and postlarval characteristics distinguishing the species of ARNOGLOSSUS.

The comparative study of the characters of the various species of *Arnoglossus* has shown, that the specific differences of the adults are to be found mainly in the numerical characters and secondly in certain peculiarities or eccentricities of structure. In form and relative dimensions the adults are alike in the known species, with exception of one form which has provisionally been included under *A. laterna* and which has a larger head and mouth (pp. 29—33). The fact, that this form thus differs from the general rule, would suggest, that it should be regarded as a distinct species, but this conclusion receives no support from other characters, whilst the variation in the common form of *A. laterna* is very great in all characters. A detailed comparison of the variety *macrostoma* with the other forms of *A. laterna* will be made under the latter species.

In the numerical characters, number of rays in the dorsal and anal fins, number of caudal vertebrae, the 5 species distinguished appear as links in an ascending series with a wide range (p. 34). In 4 of the species the range of variation is restricted and the same in each case, but in the 5th, which forms the middle of the series and overlaps two other species, the range is abnormally great and suggests, that more than one species are included under it or that the species concerned (*A. laterna*) is exceedingly variable.

The peculiarities of structure which are useful in distinguishing the adults of the species of *Arnoglossus* are (1), the elongated and expanded 2nd dorsal ray in *A. Thori* (formerly called *A. Grohmanni*), the only character that clearly distinguishes this species from *A. laterna* in the adult stages, and (2),

the elongated anterior dorsal rays (2nd—6th) in *A. imperialis*, which however is more a sexual character (pp. 29—30). The adults of the true *A. Grohmanni* of BONAPARTE also appear to have the 2nd dorsal ray longer than the others.

For the separation of the postlarval stages we have first of all differences in the numerical characters, especially in the number of caudal vertebrae (p. 34). *A. Thori* and *A. laterna*, however, cannot be distinguished from these characters alone and it is thus fortunate, that the postlarval stages of *A. laterna* have already been described from a region (North Sea), where there could be no confusion with *A. Thori*. The postlarval characteristics of the latter species could thus be determined by contrast and have proved to be widely different from those *A. laterna*. In fact, there is no difficulty in distinguishing the postlarval stages of the different species of *Arnoglossus*.

The smallest species, *A. Grohmanni*, is distinguished by its small form and small number of fin-rays and caudal vertebrae.

A. Thori is distinguished by the number of fin-rays and caudal vertebrae from all other species except *A. laterna*. From this species it is distinguished by its pigmentation and the nature and distribution of the spines (pp. 43, 46).

A. laterna is exceedingly variable, but can be distinguished in all its forms by the nature and distribution of the spines (p. 43) as also by the fact, that the postanal pigment, if present, does not extend out on to the dorsal and anal fins. In pigmentation *A. laterna* is more allied to *A. Grohmanni* (p. 46).

A. imperialis is a large copy of *A. Thori*, from which it can be distinguished by the higher number of caudal vertebrae and fin-rays.

A. Rüppeli is mainly distinguished by its very high number of fin-rays and caudal vertebrae, but also by the comparative absence of pigment and the peculiar distribution of the spines.

Comparison of the lengths at which the different species metamorphose, reveals several points of general interest, which may be mentioned particularly here. For the genus as a whole, the higher the number of vertebrae the greater the length on metamorphosis (comp. p. 34 and p. 48). Thus, the order of the species given above represents an ascending series both in regard to the length on metamorphosis and in regard to number of vertebrae (and fin-rays). Further, both are correlated with the transition from shallow to deep water. A similar parallel has been shown in the case of the genus *Pleuronectes* and it is probable, that we have here the true factors of correlation for increasing number of vertebrae in flat-fishes — and not, that the number increases geographically from south to north, a theory that has little or no basis in fact. Again it is possible, that the same rules hold good for different groups or races of one and the same species. On this basis we can understand the great variation in *A. laterna*. In the comparatively shallow North Sea *A. laterna* has the lowest number of vertebrae and metamorphoses at the smallest size; at the western end of the Channel both the number of vertebrae and the length on metamorphosis are greater; whilst in the Bay of Biscay we find a still higher number of vertebrae and greater length on metamorphosis. It is hardly necessary to add, that the depth (i. e. the depth over which the postlarval life is passed) increases as we go from the North Sea to the Bay of Biscay. As the transition between the different forms of *A. laterna* appears to be gradual and as the resemblances outweigh the differences, it seems more reasonable to accept the above explanation of the origin of the different forms than to consider them as separate species. The characters of these different forms or races and their distribution will be discussed in detail under *A. laterna*.

1. ARNOGLOSSUS GROHMANNI (Bonaparte, non auctorum).

Fig. 7. Adult specimen of *A. Grohmanni*.
From Bonaparte 1832—41 (1837).

? *Bothus tappa* Raf. 1810.

Pleuronectes Grohmanni Bnp. 1837.

D. 73—79 (80); A. 51—57; Vert. 10 + 23—24 = 33—34. (P. ?; V. 6/6; C. 17; l. l. ca. 12 + 38 = 50 ?)

(Adult characteristics: Habit oval; scales of moderate size, deciduous; greatest height ca. 33 % of total length; head ca. 25 % of total length; mouth small; eyes of moderate size; second ray of dorsal fin about twice as long as the succeeding. Colour greyish-yellow to light-brown with dark markings on the body, particularly towards the dorsal and ventral profiles, and small, black points of pigment everywhere, showing very clearly between the rays of the vertical fins. Habitat: Sicily.)[1]

Metamorphosis: This takes place about 14 mm., thus at a smaller size than in any other known *Arnoglossus*. The largest specimens of 12—13 mm. in length, are still a little distance from metamorphosis (fig. 4); the dorsal fin has just reached down to the ethmoid region, the supraoccipital spine is still large, the ventrals are not yet fully developed, though having the characteristic form and position of *Arnoglossus*. On the other hand, the air-bladder has practically disappeared as such, the first interhæmal bone is curving forwards ventrally and the intestine is sinking in, thus showing that the enclosure of the abdomen will soon take place. There is no sign as yet, however, of the pigment bars on the vertical fins, which indicate the metamorphosing stage in the other species of *Arnoglossus*. On the whole, therefore, it seems to me, that metamorphosis will take place at a length a few mm. longer than my largest specimen, that is, about 14 mm.

Postlarval characteristics. The large liver and cartilaginous pubic bar, mode of growth and position of the ventral fins, pigmentation, tentacle and growth forward of the dorsal fin, all show the *Arnoglossus* characteristics. In one character only is there any great difference from the other species, namely, the apparent absence of spines along the dorsal and ventral profiles; I have not been able to detect any with certainty.

This species has probably the smallest egg among the *Arnoglossus* species, as it certainly has the smallest larva. At 5 mm. already the interspinous regions of the D and A fins are marked off along the body and many of the fin-rays are distinct. The ural elements of the caudal fin are also formed and some 7 to 8 of the caudal rays. The ventral fins have not yet made their appearance, however, and there is only the embryonic fin above the head, where the tentacle is widely separated from the snout (fig. 1).

At 7 mm. the thickening of the tissues just behind the foot of the clavicles and below the cartilaginous pubic bar shows, that the ventral fins have been laid down; at this length also the vertical fins are fully formed and the permanent rays can be counted. The end of the notochord is completely enclosed but is not yet shortened. The air-bladder is of considerable size, lying under the 7th to 9th abdominal vertebrae (fig. 2).

At 9 mm. the ventral fins are apparent, just under the clavicles and 3 to 4 rays are free (fig. 3). At

[1] From Bonaparte (1837).

10 mm. the base of the left ventral is seen definitely to be growing forward in front of the foot of the clavicle, thus determining the subfamily to which the species belongs.

The tentacle is of the heavy and solid type, such as we find in *A. laterna*. It is present already in the earliest available specimens and, as growth proceeds, moves gradually forwards and downwards in front of the eyes, just as in the other species. The first dorsal ray in front of the tentacle is present already at 9 mm. when the tentacle has covered about half the distance down towards the ethmoid region (fig. 3). In the later stages the mode of connection of the front part of the dorsal to the ethmoid as well as the pigment prove that the species belongs to the genus *Arnoglossus* (compare figs. 4, 9, 20).

The pigment is very characteristic throughout and most like that in *A. laterna*. The postanal bar is not prominent at any time, but in the earliest stages (5 mm.) it is in evidence as an accumulation of chromatophores on the dorsal and anal interspinous regions, opposite the 16th to 18th caudal vertebrae. In still earlier stages, probably, this bar has lain across the body in this region, just as in the other species of *Arnoglossus*. From 5 mm. onwards, however, the postanal bar practically disappears, the black chromatophores spreading along the margins of the body at the base of the interspinous bones, more especially dorsally, and along the base of the caudal fin; the ventral row is in fact absent in some cases. A third, very conspicuous, longitudinal row is that along the vertebral colum, each vertebra being punctuated dorsally by a black chromatophore. In the early stages, further, there may be a ventral row of small black dots from the tip of the mandible to the anus, but this seems to be somewhat rare. On the air-bladder also there are usually 2 or 3 chromatophores of a light yellowish colour and just below the air-bladder 2 narrow, black chromatophores mark the posterior, upper wall of the abdominal cavity; but these chromatophores like the few black spots about the anus are not very conspicuous or persistent. The whole pigment may, in fact, be greatly reduced, only a few traces of the dorsal row and the vertebral row remaining. Whether this reduction and great variation is due to preservation or damage on capture, at least partially, it is impossible to say. It may be remarked, also, that if the membrane of the vertical fins is well-preserved, we find on it at the distal edge several densely black patches of pigment, at least 2 on the dorsal fin, 2 on the anal and 2 on the caudal fin. The tentacle also partakes naturally of this pigment.

Remarks. Further explanation is required, perhaps, for calling this species *Arnoglossus Grohmanni* Bonaparte. It seems a great pity to change a name which has come into common use for a certain species, but in the present instance, if we follow this procedure, what should we call this species, which agrees better in essential characters, than the species usually called *A. Grohmanni*, with the definition of Bonaparte? Except in generic characters his definition does not apply to the species later authors have called *A. Grohmanni* and the only way of reconciling the two is to follow the course suggested by Holt and Calderwood (1895) and maintain that Bonaparte was mistaken in his count of the fin-ray formula. But, unlike the other earlier Italian authors, Bonaparte is most reliable in his account of the fin-rays in the flat-fishes. Further, Cunningham (1890) has noted, that the elongated 2nd dorsal ray in the *A. Grohmanni* auct, is not at all like that figured by Bonaparte in his *Grohmanni*, but supposed the difference to be a sexual one. I have examined a large number of specimens of the *A. Grohmanni* of authors, however, both males and females, and have not yet found any which resembled *A. Grohmanni* (Bnp.) in this regard. Here we obviously have a very different case from *Bothus* and *Rhombus*, and it is only just to one of the best ichthyologists, that the name he gave to his species should be retained for the specimens which come nearest to it.

The second dorsal ray in Bonaparte's figure is more like the elongated simple rays we find in the adults of *A. imperialis* (or *A. lophotes* of authors), that is to say, it is thin and slender, only twice the length of the 3rd ray and not specially pigmented. In the *A. Grohmanni* of authors, however, the 2nd dorsal ray is a long and broad, pinnate structure, as long as the head and coloured dark-gray or black[1].

The fin-ray formula given by Bonaparte for his species is D. 80, A. 52. The *A. Grohmanni* of

[1] The figure given by Moreau (1881, III, p. 326) of "*Pleuronectes Grohmanni*" may have been taken in part from Bonaparte; it is certainly very unlike the *A. Grohmanni* of authors, nor does it agree with Moreau's own description of the latter species.

authors has D. 84—90, A. 63—70; it is obvious, as HOLT and CALDERWOOD remarked, that the two formulae cannot be made to fit. On the other hand, the number of fin-rays in postlarval specimens of the form here called *A. Grohmanni* are D. 73—79; A. 51—57, distributed in the following manner:

D.	73	74	75	76	77	78	79		A.	51	52	53	54	55	56	57	
	1	1	2	3	2	4	1	14 specimens		1	2	3	2	2	3	1	

The range of variation is thus 7 rays for both fins, but in the other species of *Arnoglossus*, where a large material is present, the range of variation in the fin-rays is more than 7 and in any case I do not think, that there need be any hesitation in accepting BONAPARTE's formula D. 80, A. 52 as belonging to this species rather than to the *A. Grohmanni* of authors.

There is comparatively little variation in the number of vertebrae in the available material of my *A. Grohmanni*. In 15 postlarval specimens 23 caudal vertebrae occur 11 times, and 24 occurs 4 times. Judging from the variation in other species, however, it is very probable that 22 occurs and 25 is also quite possible.

With regard to the remaining characteristics given by BONAPARTE for his species, it is difficult to say anything definite until adult specimens are available. For example, the "small mouth" is indefinite, though it is not specially applicable to the *A. Grohmanni* of authors. In the latter the mouth is approximately of the same dimensions as that in *A. laterna*. On the other hand, the head is contained about 4 times in the total length in BONAPARTE's species, whereas in the *A. Grohmanni* of authors it is only about 5 times. The proportions of the body, colouration etc. hardly lend themselves to specific characterization, as shown above. The specific characters in this genus are found, in fact, just in the size of the head and mouth, number of rays and vertebrae, and in the elongated dorsal rays. As already mentioned, the elongated 2nd dorsal ray in BONAPARTE's figure of his *A. Grohmanni* does not resemble that in the *A. Grohmanni* of authors, and it may also be noted, that in BONAPARTE's figure his *A. Grohmanni* is given a fairly distinct caudal peduncle, whereas this is not present in any of the other species of *Arnoglossus* (cf. text-figs. 7, 8, 9).

Distribution. This species appears to be restricted to the Mediterranean; in fact, there are no records of it west of the longitude of Greenwich, though this does not necessarily mean, that it does not occur as far west as Gibraltar, as will be shown below. East of the meridian of Greenwich, however, it has been found practically everywhere in the Mediterranean, from the Balearic Isles in the west to the Black Sea in the east and from Corsica in the north to Tunis in the south. The precise details of its occurrence, as shown by the records of the "Thor", can be gathered from the following Table and the accompanying Chart.

Chart 1. Distribution of *A. Grohmanni* (Bnp.).
○ — Postlarval specimens taken by the "Thor".

These stations include nearly all the shallow-water stations investigated by the "Thor" and the deep-water stations included (215, 209, 126, 172) lie close to the land. The species is thus obviously a

shallow-water form and would consequently have been taken in greater numbers, had the "Thor" not been specially engaged in investigating the deeper waters. Its wide range of distribution also shows that it must be common everywhere in the Mediterranean, even if not specially abundant. As further evidence that it is a shallow-water form we have, also, that its postlarval life appears to be quite short. As shown above, it

Region	Balearic Sea				Tyrrhenian Sea E. of Corsica	Tunis Bay	Strait of Messina	Dardanelles	Bosphorus and Black Sea		
Depth at Station m.	75	1050	64	>2000	600—620	80	>100	85	60	1090	65
Month of capture ...	August 28—31				July 10—19		August 10—21				
0—50 m.	5	1	1	1	1	2	1		5	1	
65 m.								3			1
100 m.	3					1				1	
Number of specimens	8	1	1	1	1	3	1	3	5	2	1
Stations	213	215	207	209	126	136	193	179	171	172	173

metamorphoses already at a length of about 14 mm. and the time required for passing through the larval and postlarval stages, by comparison with what is known for *A. laterna*, also a shallow-water form, need not be more than 3 months. It has not been taken in June or September (though on August 31st), nor on the great majority of the deep-water stations. On July 19th already one specimen (St. 136) was beginning metamorphosis; on August 21st one specimen was only 5·5 mm. long, and on August 31st 4 specimens were below 10 mm. The spawning-time would thus extend from May into August and the later postlarval stages should still be found in September.

That the species has not been taken west of the Balearic Isles seems to me due partly to accident and partly to the fact, that the waters referred to were not investigated at the best time for the capture of the postlarval stages of this species. The Alboran Sea and Strait of Gibraltar were investigated in June and September. In June we should only expect to find the eggs and early larval stages, which have not yet been distinguished. In September the great majority have already metamorphosed and taken to the life on the bottom, and it would thus be a great chance if any postlarval specimens were taken at that time, unless specially sought for nearer the land than the "Thor" was working.

It need hardly be said, that no specimens of this species were obtained on the winter cruise in December, January and February,

When we consider the wide distribution this species has in the Mediterranean, it seems remarkable, that no notice has been taken of it since BONAPARTE's time. I have found nothing in the literature to indicate, that unidentified larvae might belong to it. This is even more remarkable than the fact, that the adults have not been mentioned, for the adult forms of *Arnoglossus* show, superficially, such a great resemblance to one another, that only a very thorough examination can distinguish them. The adults of *A. Grohmanni* may have a great resemblance superficially to *A. Thori* (*A. Grohmanni* auctorum) or *A. laterna* and thus pass unnoticed unless a special search was being made for them. The existence of the species in the Mediterranean cannot be doubted.

2. ARNOGLOSSUS THORI nov. nom.

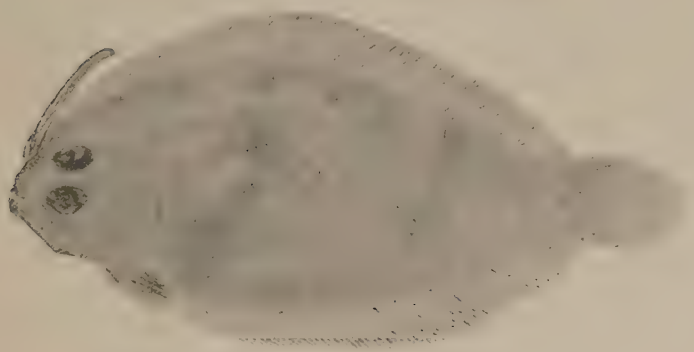


Fig. 8. Adult ♀ of *A. Thori.* Bay of Biscay. n. s.

Pleuronectes Grohmanni Canestrini 1861, Moreau 1881 (et auctorum).
Arnoglossus Grohmanni Günther 1862 (et auctorum).

Eggs and postlarval stages:
Raffaele 1888; Graeffe 1888.
Holt, 1898, 1899.

D. 84—(85—89)—92; A. 63—(64—67)—69; C. 17; P. 10/9; V. 6/6: Vert. 10 + 27—(28, 29)—30 = 37—(38, 39)—40[1]
Scales: 12—13/14; 13—14 + 36—39 = 49—53.

Adult: Habit oval, more or less pointed or rounded in front; scales deciduous but perhaps more fixed than in *A. laterna.* By comparison with the total length (including tail) the greatest height is 35 %, distance of greatest height to beginning of caudal fin 45 %, caudal fin 18 %, pectoral fin of ocular side 12—13 %, length of head 19—20 %, 2nd ray of dorsal fin 16—21 %. By comparison with the head, the longitudinal diameter of the upper orbit is 37—39 %, the left mandible 52 %, the premaxilla 33 %; the upper orbit is thus generally greater than the premaxilla. Colour grayish red to brown with darker markings, especially on the first dorsal rays and two or three darker patches on the lateral line; the younger specimens with a sprinkling of brown spots especially on the fins; left ventral with a darker spot on the membrane from the 4th to 6th rays in both sexes; this membrane extended posteriorly to connect with the body. In mature specimens the first three to four dorsal rays are of a coal-black colour in both sexes, but in immature specimens only the 2nd ray has this colour, the 1st ray being usually white to near its base and the 3rd and 4th merely spotted. The 1st, 3rd, 4th and perhaps 5th dorsal rays and the rays of the left ventral are also slightly elongated in mature specimens. Secondary sexual differences not detected.

Spawning period: March to July; December—January. Length at first-maturity: 70—80 mm.; maximum size ca. 15 cm.

Metamorphosis. This takes place between 20 and 25 mm.; a large number of specimens between 18 and 21 mm. show distinct indications of approaching metamorphosis, 3 specimens of 22—23 mm. and 1 at 26·5 mm. are completely metamorphosed, whilst 1 specimen at 24 mm. has not yet metamorphosed.

When metamorphosis occurs, the "tentacle" of the postlarva, contrary to the earlier view, is thrown off as a rule and the long, pinnate or flap-like structure of the adult is a new growth. The evidence for this conclusion is of two kinds, indirect and direct. Firstly, a postlarval tentacle is present in all other

[1] The numbers in brackets indicate the most frequent occurrences.

species of *Arnoglossus* as well as in the genus *Bothus*; in the latter genus it is thrown off at a very early postlarval stage, in *Arnoglossus* it certainly remains as far as the metamorphosing stages, but no other species (except perhaps *A. Grohmanni*, see above) has such a structure after the adult form has been assumed. It has to be noted also, that the tentacle has a special function in the postlarval life (see above p. 39) a function that ceases when the pelagic mode of life is given up. Secondly, the process of regrowth can be followed directly in some metamorphosed specimens in my material (cf. Pl. III, figs. 32, 33); further, in many specimens about to metamorphose the tentacle is broken off short, just as in other species of *Arnoglossus* at the same stage. This may be accidental, of course; nevertheless, the main point is, that when broken off a new growth appears in *A. Thori* but not in the other species.

On the other hand, there is a fully transformed specimen of 22 mm. in my material, which shows that the elongated 2nd dorsal ray of the adult may also arise from a transformation of the tentacle of the postlarva. In this specimen the 2nd dorsal ray is long and thin, longer than the head, and greatly resembles the tentacle of the postlarva.

It is quite possible that both methods occur, but judging from my specimens the former method, i. e. that the pinnate structure of the adult is a new growth, is the general rule. This structure is fully developed already at a very early stage and is not a special characteristic of the adult male, as CUNNINGHAM suggested (1890). A large number of specimens (26) between 39 and 50 mm. in my material all have this character, its relative size being practically the same as in the adults but its colour paler. This applies to both males and females. By means of this character the young stages can be readily distinguished from those of *A. laterna*.

During and after metamorphosis the pigmentation of the postlarva changes its character, the postanal bar and longitudinal rows, and the chromatophores on the air-bladder and about the lower end of the abdomen becoming supplemented by a series of bars on the dorsal and anal fins and interspinous regions, and irregular groups of small chromatophores appear on the head and anterior part of the body, spreading gradually backwards with the growth of the scales (Pl. I, fig. 10). It has to be noted, further, that in this species the pigment over the region of the air-bladder persists after the latter disappears as such and that the well-marked postanal bar near the tail remains as the most prominent bar on the fins. The latter characteristic is of importance, enabling *A. Thori* to be distinguished from *A. laterna* (cf. figs. 10, 18), which at the stages shortly after metamorphosis might otherwise be confused with it. This characteristic also distinguishes the newly metamorphosed stages of *A. imperialis* (see fig. 11). At a slightly later stage, however, these bars also become less prominent, though persisting faintly until maturity is reached, owing to the grayish yellow ground-colour developing and becoming covered over with darker, brownish spots. At 40 mm. each bar is merely represented by a few brown spot on the fins.

Postlarval stages. The most striking features of the postlarval stages of *A. Thori* and, if we exclude the vertebrae and fin-rays, the specific characteristics are found in the distribution of the pigment and spines or spined plates.

The early larva according to HOLT (1899, p. 81) is ca. 2 mm. long when it escapes from the egg, which is ca. .7 mm. in diameter. The distribution of the pigment is then in great part the same as in *A. laterna*, that is, there is a well-marked postanal bar about halfway between the anus and end of notochord and another across the body at the posterior part of the abdomen (the air-bladder is not yet present); further, patches of similar pigment on the dorsal and anal, embryonic fins and on the anterior part of the body and head. In addition to the foregoing, *A. Thori* is said to be distinguished by a 2nd postanal bar posteriorly at the place where the notochord later bends upwards[1]; further, the colour of the pigment, instead of being yellowish as in *laterna*, is decidedly orange to red.

[1] This terminal pigment is certainly present in *A. imperialis* and almost certainly also in the dark form of *laterna* (cf. figs. 19, 22).

The youngest postlarval stages in my material, 6 mm. (Pl. I, fig. 5), join on well to the above description of the earliest stages. The three transverse bars of pigment, abdominal, postanal and notochordal, are still present and the colour, even in formaline specimens, is distinctly darker, rusty brown, than the pale-yellow of *A. laterna*. The pigment below the end of the notochord disappears early, however, as a rule (7 mm.), though a trace of it has been noted under the end of the notochord in a specimen of 11 mm.; the other two bars, in contrast to what occurs in *A. laterna*, remain very conspicuous (figs. 6, 7). Further, it may be noted, that the early larval pigment on the head and anterior part of the trunk has entirely disappeared in my earliest specimens; also, that the larval period must last for a considerable time, taking the larval period to mean the interval between the exclusion from the egg until the permanent fin-rays begin to appear, in this case from 2 to 7 mm.

Even at the earliest stage, before the interspinous regions are completely outlined dorsally and ventrally (7 mm.), another character has appeared, which distinguishes *A. Thori*. Under a moderate magnification, 10 times, an irregular row of small points can be detected along the ventral margin of the abdomen, under the large liver, and under a higher power (50 times) these points resolve themselves into spines arranged in groups of 5 or 6 on small scale-like plates, 5 to 8 of these plates may be present in this region. At the same time several large spines, either free or on plates or both also appear at the base of the tentacle above the head (figs. 5, 6 and scheme p. 43).

It is worth noting, that these spines are equally developed on the two sides of the body, both in this and all later stages, whereas the pigment in the later stages becomes fainter on the future blind side than on the other.

At 8—9 mm. the interspinous regions are marked off along the dorsal and anal fins, beginning in the middle part of the body and spreading forwards and backwards; at the same period the end of the notochord becomes bent upwards. The spined plates develop and increase in number *pari passu* with the development of the interspinous regions. At this stage also the cartilaginous bar ventral to the abdomen retires a little upwards just behind the base of the clavicles, showing that the horizontal, anteriorly projecting branch of the pubic bone is forming. The dorsal row of interspinous pigment may already be present at this stage (fig. 6, 7).

At 12 mm. the postlarval characteristics are well-developed, though the end of the notochord is not yet enclosed. The air-bladder is specially large in this species, extending from the 7th to the 10th abdominal vertebra. The ventral fins are still rudimentary, but the horizontal branch of the pubic bone is distinctly formed, lying behind the clavicles, whilst the middle rays are just about to break through the skin (fig. 8). With regard to the pigment, it may be noted, that the postanal bar, which, before the interspinous regions develop, lies across the body of the tail between the 18th and 21st abdominal vertebrae, has at this stage spread out from the body on to the interspinous regions and partly also on to the dorsal and anal fins. There it comes to lie between the 69—75 or 70—76 dorsal rays and 46—52 (45—51 or 49—54) anal rays, counting from in front. As the present species and *A. imperialis* are the only *Arnoglossus* species which have the postanal bar permanently well-developed in the postlarval stages, this character enables these species to be distinguished at a glance in these later stages; in the postlarval stages of *A. imperialis*, however, the postanal bar lies about 10 rays further back. The dorsal interspinous row of pigment is now well-marked, as also a row dorsally to the vertebral column from the abdomen to the fifth last vertebra, but the anal interspinous row only consists of comparatively few and small spots.

It is evident from the above, that *A. Thori* is a particularly well-marked form at all stages. Cases do arise, however, where it is not very easy to distinguish this species from *A. laterna*, namely between 8 and 12 mm., before the interspinous regions have fully developed and when the postanal bar is still in part on the body, thus at a stage when this bar is also on the body in the other species. Such difficulties

only arise with damaged specimens, however, in which the spined plates on the abdomen have been rubbed off, whilst the spined plates on the interspinous regions have not yet sufficiently developed to be recognised as such. In these cases the distinguishing characteristics may be fined down to the vanishing point. If coloured pigment is present, the darker tinge and more copious pigment distinguishes *A. Thori*, but in damaged specimens this pigment is usually also defective; again, if the specimen has 27 caudal vertebrae, it is certainly *A. Thori*, but 28 and 29 are more frequent than 27 — thus the same as in *A. laterna*. In such cases the specimen should be examined under a high magnifying power, as marks where the spined plates have been can usually be detected along the ventral margin of the abdomen and the nature of the spines along the interspinous regions (whether aggregates or plates, see p. 42) may also be discovered. Further, spined plates are frequently present on the descending coil of the intestine and on the liver as well as sometimes on the front margin of the ascending coil of the intestine. I have even found a large spined plate on the air-bladder. Whether these are normal occurrences — they are certainly frequent and appear normally in *A. imperialis* on the liver and intestine (see later) — I am unable to say, but the discovery of spined plates at any of these places is a certain indication of this species (excluding for the moment *A. imperialis*). Failing these positive indications of *A. Thori*, the specimen is most probably *A. laterna*.

Beyond 12 mm. *A. Thori* is remarkable for its high and robust form, the height (without fins) being 50 % of the length (without caudal fin). The postlarva of *A. imperialis* also assumes this form, but at a much later stage (fig. 26), whilst in *A. laterna* as a rule the form remains slender or elongated throughout postlarval life, the Channel specimens only excepted, as will be mentioned under *A. laterna*. This broad or high form, with the well-marked postanal bar, the large air-bladder, the spined plates along the cartilaginous pubic bar and interspinous regions and the small number of caudal vertebrae (27—29) make the work of identifying the postlarval stages of this species between 12 and 20 mm. very easy. About 18 mm. signs can be noticed of approaching metamorphosis; the spines and teeth begin to disappear, the large liver bends upwards at its tip and the first interhaemal spine bends forwards at the point to enclose the abdominal cavity ventrally, thus causing the ventral line of the body to straighten out between the ventral and caudal fins and so on. One of the last postlarval characteristics to disappear, contrary to what we find in *A. laterna*, is the air-bladder. This remains large until a late stage in metamorphosis, thus indicating that metamorphosis must for the most part take place pelagically. The ventral fins are only fully formed and the left ventral reaches forward to the urohyal just before metamorphosis begins, thus about 18 mm. (figs. 9, 10).

Remarks. My material of *A. Thori*, so far as the adult form is concerned, is not so extensive as might be desired. It consists, apart from the postlarval stages, of 68 specimens between 39 and 102 mm. in length. This number would be sufficiently large to give a good idea of the variation in the principal characters, but the great majority are small, between 40 and 60 mm., and the measurement of essential characters, such as the mouth, is not so readily carried out, nor so reliable on such small specimens. Apart from the vertebrae and fin-rays I have, therefore, been obliged to restrict myself to about 20 specimens.

The greater portion of the material was taken in December at Taormina in Sicily. The largest was 86 mm. On measuring the length of the 2nd dorsal ray in the larger specimens I was somewhat surprised to find, that in several specimens the 1st and 3rd rays were also distinctly longer than the following rays and this led to a close examination of the reproductive organs. As will be shown below, these proved to be mature already at this length, at least they would have spawned in the following spring. Some specimens received later from Santander and of the same length were also found to be fully ripe in March. Lastly, a specimen of 102 mm. taken in the Mediterranean in July had ripe eggs in the ovary. There is no doubt, therefore, that this species spawns already when just over 70 mm. in

length. Further, the spawning-time extends from April to late summer, the specimens obtained in March being almost ready to spawn, that of July not yet spawned. It will be shown later how the evidence from the larvae agrees with this.

The greatest height in 16 specimens, including males and females, mature and immature, varies between 32 and 36 % of the total length with the tail, 12 of the specimens having 34—36 %. In the same specimens the distance from the greatest height to the base of the caudal fin measured along the lateral line, varies between 111 and 140 % of the height, 120—130 % being the commonest frequencies.

In 21 specimens the length of the head, measured from the premaxilla (closed) to the first scale of the lateral line on the body, thus to the posterior margin of the posttemporal, is 18—21 % of the total length, distributed in the following manner:

		18	19	20	21
♂	immature		3	2	
	mature	1	3	1	
♀	immature		2	3	1
	mature		1	3	1
		1	9	9	2

The average is thus 19·5; the material is naturally too small for close analysis.

The length of the 2nd dorsal ray is extremely variable, probably due to some extent to injury. In 2 mature specimens, one male and one female, it was longer than the head, namely 24 % and 21 % of the total length respectively. In all the other specimens it was smaller than the head, varying from 11 to 18 % of the total length. The variation is common to both males and females, mature and immature. Thus, in one mature female it is only 11 % of the total length, or but little more than half the length of the head; in a mature male specimen again it is only 12 %. The most usual frequencies vary between 14 and 18 %. It is obviously impossible to state an average; if the shorter length is due to injury and such injury is of frequent occurrence, followed by regrowth, all that can be said is, that the maximum length may equal or exceed the length of the head.

Whilst no difference can be detected in my specimens between immature and mature as regards the length of the 2nd dorsal ray, such a difference seems to exist with the regard to the 1st, 3rd and possibly 4th rays. In the immature specimens, the 3rd and immediately succeeding rays are all alike, that is, thin and slender and about 6 % of the total length, the first differing only in being slightly broader and free to near the base. In mature specimens, however, and in both males and females, there is an appreciable, if slight difference in length between these rays and those from the 6th onwards. They become broader, thus more palp-like, and increasing in length their ends are freer. Their average length then becomes 7—8 % of the total length. As the specimens were mature only for the first time, it is probable, that the difference between the rays increases with increasing length or age. As already mentioned also, the colour of these first rays of the dorsal fin is very variable; usually the 2nd ray is a deep-black and the 1st ray colourless, but both the first and third may be a deep-black, whilst, on the other hand, the 2nd as well as the other rays may be grayish.

Though no measurements were made of the left ventral, it appears that this also undergoes a similar change to the 1st and 3rd dorsal rays, the thin rays becoming thicker and longer. In this species also as in *A. laterna* and *imperialis* the left ventral has a distinct black patch of pigment on the membrane of the 4th to 6th rays. It is possible that the pigment patch grows darker with maturity, like the first dorsal rays, the darkest patch is certainly present in a mature male, but there is so much variation, that a larger material of older specimens would be necessary to determine the matter satisfactorily.

The evidence for the maturity of the December specimens mentioned above may be referred to here. In 6 females from 56 to 68 mm. in length, the ovary measured from 10 to 13,5 mm., thus about 20 % of the total length. In 3 females measuring respectively 73, 74 and 80 mm. the ovary measured 24, 29 and 29 mm., thus about 33 % of the total length; in the ripe specimen of July, 102 mm, the ovary measured 26 mm. The ovary on the ocular side was measured in each case. There can hardly be any doubt, therefore, that these specimens were preparing to spawn in the ensuing spring. In 4 males of the same length,

68 to 77 mm., the testes were distinctly swollen by comparison with the condition in other smaller specimens, so that these also would have spawned in the following spring. Lastly, a female specimen of only 71 mm., obtained from Santander in March, had the ovary far advanced in development, its length being 33 mm. or 47 % of the total length, thus similar to the above, but its thickness was much greater.

The most important specific characters, apart from the elongated 2nd dorsal ray, are to be found in the size and relative proportions of the mouth. The dimensions taken here are the extreme length of the left mandible and the extreme length of the left premaxilla. The mandible alone does not give a sufficient representation of the size of the mouth, but both together do. The premaxilla is better than the maxilla, since the upper end of the latter is not so capable of exact localisation. On the other hand, care has to be taken to get the lower end of the premaxilla correctly, but the flap of skin covering it is a good guide and after a little practice the tip of the bone underneath is found to be a good support for the pointers. In addition, the longitudinal diameter of the upper orbit has been measured, not the eye which is less reliable. The dark ring of skin round the orbit is a good guide and measuring to the extreme border of this the bony socket below gives a good support to the pointers. In all cases of measurement, whether of the head or body, it may be said, that the accuracy of the results depends essentially on the measurements being carried out always in the same way and according to the same plan. It is also important, that the structure measured should be as solid as possible and not subject to accidental pressure or other causes of variation. The variability of the results is a good index of the value of a character, since the concentration of the frequencies about a few variants indicates, that the measurements have been made satisfactorily; a great dispersion of the frequencies, on the other hand, might well be due to the measurements and not to any natural cause. All the measurements discussed in this work, both for this and other species, have been rigorously carried out in the same way, so that the results for the different species are directly comparable.

Mandible	47	48	49	50	51	52	53	54	55	56
immature		1		4			2	3		
mature	1			5		4				1
	1	1		9		4	2	3		1

21 specimens Average 51·3

Premaxilla	30	31	32	33	34	35	36
immature			4	3	1	2	
mature	3	1	1	1	2		3
	3	1	5	4	3	2	3

21 specimens Average 33·0

Upper orbit	32	33	34	35	36	37	38	39	40	41	42
immature	1	1	1	1	3	1	1				1
mature			1		2	3	1	3	1		
	1	1	2	1	5	4	2	3	1		1

21 specimens Average 36·7

As the specimens are but few in number it is not possible to carry their analysis into very great detail, but a distinction has been made between immature and mature specimens, the sexes being taken together. The following series show the variation observed in the three characters mentioned; the results are expressed in percentages of the length of the head.

It will be seen, that there is a great deal of variation in the three characters, more than is natural; this must be ascribed partly to the fact, that the measurements were only taken to half a millimeter and partly to the difficulty of measuring such small specimens accurately. The orbit suffers most in both cases and the only safe conclusion we can draw here is, that the orbit is certainly larger as a rule than the premaxilla. As will be seen, this is in itself an important result. A difference between the immature and mature cannot be concluded from this material, for any of the characters, though it seems more probable in the case of the orbit.

With regard to the premaxilla and mandible, there is reason to believe, that the range of variation, though apparently considerable, is fairly representative. In the first place, these dimensions can be measured very accurately and in the second place, it will be shown later, that *A. imperialis*, which is very like this species in many ways, has almost exactly the same range of variation and average in these two characters,

and this in a very much larger material. The mandible is a little more than half the length of the head, whilst the premaxilla is just one-third of the same length. The premaxilla is about 65 % of the length of the mandible.

It is not necessary to discuss in detail the other characters which have been measured, pectoral fins and caudal fin. They are likewise very variable and the proportions given in the diagnosis are merely averages.

The caudal vertebrae have been counted in a considerable number of specimens, both postlarval and older. As already mentioned, the number of abdominal vertebrae has always been found to be 10 in all species of *Arnoglossus*. The variation in the number of caudal vertebrae is shown in the following series:

	27	28	29	30
lateral stages (67)	3	43	21	
postlarval stages (45)	6	19	18	2
112 specimens	9	62	39	2

The dominant number is 28 caudal vertebrae and 101 or over 90 % of the specimens have 28 or 29 vertebrae; the arithmetic average is 28 · 3 with a probable error of ± · 04.

The number of fin-rays have been counted in 54 specimens, 26 of the later and adult stages and 28 postlarval specimens. The variation is as follows:

D.	84	85	86	87	88	89	90	91	92
later stages	2	5	5	4	5	2	2	1	
postlarval stages	2	3	4	6	6	5	1		1
54 specimens	4	8	9	10	11	7	3	1	1

A.	63	64	65	66	67	68	69
later stages	1	6	6	5	4	3	1
postlarval stages	4	5	5	6	5	2	1
54 specimens	5	11	11	11	9	5	2

The postlarval specimens here, as in the case of the caudal vertebrae, agree very well with the later stages and it will be noticed, that in each case the variation in the postlarval specimens has a greater dispersion, i. e. a relatively greater frequency away from the centre, than in the adults. This may be accidental but may also be due to a process of natural selection, by which a weeding out during growth leaves the remainder more alike or more true to the average.

The extreme range of variation is 9 rays for the dorsal but only 7 for the anal, namely, 84 to 92 and 63 to 69 respectively. Judging from the abrupt termination at the lower end, it might seem as if 83 or even 82 for the dorsal and 62 or even 61 for the anal might occur. But it is quite evident, that the fin-ray formula given by Bonaparte for his *Grohmanni*, namely D. 80, A. 52, is quite incompatible with the present species. The predominant range, i. e. containing 50 % of the variants, is restricted to only 3 rays in each case, but it will be noticed, that each of 4 variants is almost equally frequent, namely 85—88 for the dorsal and 64—67 for the anal. Over 70 % of the frequencies are included within these values and we may call this the probable range of variation, meaning therewith, that the number of fin-rays in any chance specimen will lie within this range in all probability and that at least 50 % of any other large group of specimens will have this same range. It is obvious, further, that this range of 4 rays may also be used for comparison with other species.

The number of rays in the left pectoral has also been counted in a few specimens, with the constant result 9 + 1, i. e. 9 long rays and one short ray uppermost.

The number of scales on the lateral line of the body has been counted in 9 specimens and also shows not a little variation. On the arched part of the lateral line over the abdomen, 13—15 scales were found, 14 in 5 cases, on the straight part 36—39, 38 occurring 4 times; the total number thus varies between 49 and 53, 51 and 52 being the most frequent. In 3 specimens the vertical series showed 12—13/14.

[1] In 4 adult specimens received from the Oceanographical Museum of Monaco in February 1913 I find D. 85—89, A. 64—65. In one of these the elongated dorsal ray seemed to be the first, the first D ray being represented only by a papilla.

For the determination of the growth and age, the scales in *A. Thori* are not very good subjects, much less so than in *A. laterna*. The difficulties arise not only apparently from the continuance of the growth during the winter, especially the 1st winter, but also from the irregular growth thereafter of the scale itself, one part or wedge growing strongly at one time, another at another, so that the circular lines become irregular. From a comparison of different sizes, in all 10 specimens, however, it seems certain, that *A. Thori* grows very slowly. Thus, specimens taken in December at Taormina, Sicily, were in their first winter at 52 and 53 mm., in the 2nd winter at 63, 68, 77 and 80 mm.; the last 2 were certainly mature. Again, 2 mature specimens of 71 and 82 mm., taken in March(?) at Santander, had only 1 definite ring, whilst 1 of 89 mm. had 3 rings. Lastly, a specimen of 102 mm. from the Mediterranean, taken in July, had apparently 3 growth-rings. These results depend, however, on the 1st ring; the position of this, or where it should be, has only been determined by comparison with the specimens of 52 and 53 mm., which appear to be in the beginning of their first winter.

Spawning-period of *A. Thori*. But little definite is known regarding the spawning-period of this species. RAFFAELE (1888) merely states in general, that the species of *Arnoglossus* and *Bothus* spawn in April. GRAEFFE (1888) gives December and January for the Gulf of Trieste, noting the same months for *A. laterna*. HOLT (1899) found the pelagic eggs in the beginning of April at Marseilles. The mature specimens in my possession point to a spawning-time in spring. Thus, a number of mature specimens taken at Taormina in December were preparing to spawn and 3 from Santander in the Bay of Biscay had the sexual organs nearly ripe in March. But my largest specimen, a female taken at the "Thor" station 142 in July, though ripe had not yet spawned.

The evidence from the pelagic specimens also indicates a prolonged spawning-period. If we consider, that specimens up to 10 mm. have been 6 weeks in the water and those 18 mm. and above at least 3 months, then we can form some approximate idea of the length of the spawning-period from the following data.

	June	July	August	September	December	February
10 mm.	89	38	31	33		1
18 — and above	7	3	12	7	2	

The large specimens taken in June were probably spawned in March, thus agreeing with HOLT's statement; the small specimens taken in September were spawned in July or beginning of August. The two large specimens taken in December may have been spawned in August or earlier, assuming a very prolonged pelagic existence, but the small specimen taken in February could hardly have been spawned earlier than December. There is thus some confirmation of GRAEFFE's statement, that this species spawns in December and January. More investigations in late autumn and winter will probably show, that *A. Thori*, like the dab (*P. limanda*) and *A. laterna*, has a very prolonged spawning-period, some specimens at any rate spreading the period practically over the whole year.

Distribution. HOLT (1900) has shown, that *A. Thori* is not rare on the south coast of England; it has also been taken in the Bristol Channel as well as on the south-west and northern part of the west coast of Ireland. Further, I have received 3 specimens from Santander in the Bay of Biscay. It is certain, that it is domiciled and spawns at all these places. Further south, it has been recorded by STEINDACHNER (1868) from the Bay of Cadiz and the south coast of the Spain; in February 1912 three postlarval specimens (7—14 mm.) were taken at 23° 35′ N., 17° 14′ W., thus near the Canary Islands and other 2 (7 mm.) at 23° 46′ N., 17° 5′ W.; these had 28 caudal vertebrae.

The accompanying chart shows its distribution according to these records and the investigations of the "Thor". It will seen, that the species extends throughout the Mediterranean on both the northern

and southern side as far as the Sea of Marmora, but it was not taken in the Levant. It is probably the commonest species of flat-fish in the Mediterranean.

The distribution of the pelagic specimens over great depths is shown by the following summary.

Depth at stations	0—100	100—500	500—1000	1000—2000	> 2000
No. of specimens	52	85	46	53	68

Thus, of 304 specimens over 36 % were taken over depths of 1000 meters and more, whilst 55 % were taken over depths greater than 500 meters. This proportion is very large, even when we make all-

Chart 2. Distribution of *A. Thori* nov. nom.
× = Known occurrence of adults. ○ = Postlarval specimens taken by the "Thor".

owance for the fact, that the "Thor" fished more over these great depths (see Introduction p. 5). And another curious thing is, that *A. Thori* was more abundant over great depths than *A. laterna* both absolutely and relatively (see later). Since the numbers taken over great depths included all sizes from the smallest to the largest (see for examples stations 108 and 112 in the main Tables), we might be disposed to think, that the adults both lived and spawned out in these great depths. This would also apply, though to a less extent to *A. laterna*. But the more probable explanation is that already suggested in the Introduction, namely, that the currents of the Mediterranean tend to carry the pelagic stages offshore over great depths. *A. Thori* is more abundant there than *A. laterna* presumably because its pelagic life is more prolonged. Whether the adults can live at these great depths is unknown; the greatest depth at which they were taken by the "Thor" was 98 meters.

3. ARNOGLOSSUS LATERNA Willughby.

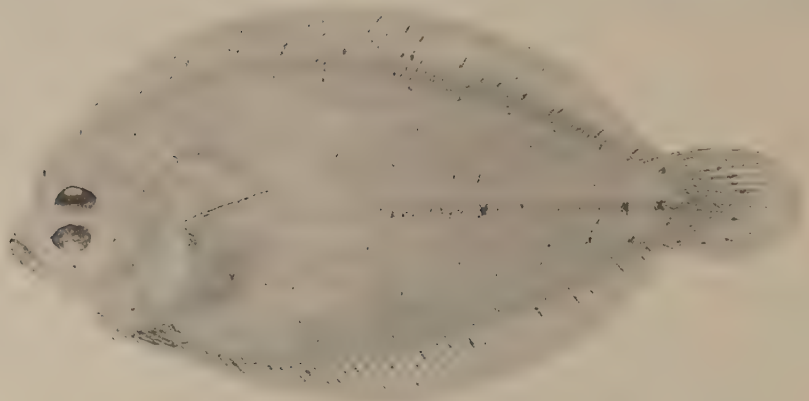


Fig. 9.
Adult ♀ of *A. laterna*; Southern North Sea. n. s.

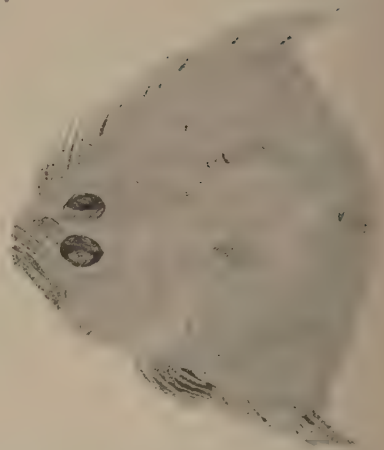


Fig. 9a. Adult ♂ of *A. laterna*; head. Plymouth.

?Arnoglossus seu *Solea lævis* Rondelet 1554.
Arnoglossus seu *Solea lævis* (*laterna*) Willughby 1685.
Pleuronectes laterna Walbaum 1792.
? — *casurus* Hanmer in Pennant 1812.
— *Leotardi* Risso 1810; *? Rhombus nudus* Risso 1826.
— *arnoglossus* Bonaparte 1832, Canestrini 1861, Moreau 1881.
— *conspersus* Canestrini 1861.
Arnoglossus laterna Günther 1862 (et auctorum).
Platophrys (*Arnoglossus*) *laterna* Smitt 1892.

Eggs, larval and postlarval stages:
A. laterna Ehrenbaum 1897, 1905; Holt 1898, 1900.

D. 82—(88—93)—98; A. 63—(66—71)—74; P. 11—12/9—10; V. 6/6; C. 17; Vert. 10 + 27—(29, 30)—32 = 37—(39, 40)—42.

Scales: 11—12/12—13; 12—15 + 35—44 = 50—56.

Adult characters: Habit oval to pyriform; scales very deciduous. With respect to the total length, the greatest height without vertical fins is ca. 33 %; with respect to the greatest height the distance of the greatest height to beginning of caudal fin is ca. 140 %. Longitudinal diameter of upper orbit generally less than length of premaxilla. Scales on blind side smooth, those of eyed side with 40—60 small spines. The first 5—6 rays of dorsal fin free at the distal end, but not longer or only slightly longer than the succeeding rays. No appreciable sexual differences. Colour of eyed side uniform greyish with reddish tinge caused by innumerable small dots of reddish pigment on skin covering the scales, darker in older specimens; when scales rubbed off the reddish tinge not apparent; occasionally darker markings on the body and above the snout, and a dark spot on the left ventral; as a rule also small brownish spots dotted over body and especially the fins (*conspersus*), but these may be very faint or absent.

var. *macrostoma:* length of head 21—22 % of total length; length of the mandible 61—67 % of length of head; length of premaxilla 41—46 % of length of head. Habitat Mediterranean.

var. *microstoma:* length of head 18—20 % of total length; length of mandible 50—56 % of length of head; length of premaxilla 34—40 % of length of head. Habitat Mediterranean and northern waters.

Spawning period: March to August. December—January? Size at first-maturity 70—90 mm., maximum size ca. 17 cm.

Metamorphosis: 16—30 mm. The migrating eye passes under the first part of the dorsal fin, which becomes loosened from its attachment to the snout. The "tentacle" or prolongation of the 2nd dorsal ray disappears at this time, as also the postlarval teeth, spines and air-bladder. The abdomen becomes enclosed below; permanent scales appear on the caudal peduncle and the first beginnings of the lateral line system on the head.

Length on metamorphosis in different regions:

North Sea	16—20 mm.	Bay of Biscay	26—30 mm.
Channel	20—27 —	Mediterranean	over 20 —

Postlarval characteristics: The general characteristics of the postlarval stages of *A. laterna* are already well-known and need not be redescribed here. The main points to be discussed and illustrated have reference to the main distinguishing characters and their variation.

The characteristics held in common by all the forms of *A. laterna* and which distinguish them from the other species of *Arnoglossus* are, firstly, the spines and secondly the pigment.

The spines first appear, to the number of 5—6, above the head near the base of the tentacle at 6—7 mm.; the same stages of *A. Thori* and *A. imperialis*, the only species with which *A. laterna* might be confused, have already well-developed spined plates ventrally along the cartilaginous pubic bar. At the same period a few dark points just behind the lower end of the clavicles show that the spines, which later form a dense cluster on the base of the ventral fins, are beginning to develop there. The rows of spines on the interspinal regions appear as the latter develop (from 7 mm. onwards). By 12 mm. the permanent dorsal and anal rays are well-developed and so also are the spines. From this length onwards the character and distribution of the spines enable *A. laterna* to be readily distinguished from the other species (compare figures p. 42 and p. 43). The only difference between the different forms of *A. laterna* is, that the spines are slightly larger and more conspicuous in the larger forms of the Channel and Bay of Biscay. The sameness of the spines, when we consider the differences in the other species, is an argument in favour of regarding these different postlarval forms as belonging to one and the same species.

In regard to the pigmentation of the postlarval stages of *A. laterna*, two extremes may be distinguished. The one form is pale, that is with little or no pigment (Plate II figs. 14—17), the other (PETERSEN's "*Grohmanni*") has a more or less abundant supply of black pigment (Plate II figs. 19—21). In the beginning there is a postanal bar on the body and some chromatophores about the anus and rectum; in both forms also the coloured pigment, particularly on the air-bladder is yellow. In addition, the dark form has a row of dark spots along the base of the interspinous regions with, perhaps the most diagnostic feature, a few on the tail and otocystic region (cf. figs. 20—21 on Pl. II). As development proceeds, the dark pigment diminishes and tends to disappear entirely in the pale form; already at 10 mm. there may be only one or two black chromatophores to mark the postanal bar and one or two at the anus. In the dark form, however, the black pigment persists longer and may be permanent.

From an examination of the northern specimens, one might be disposed to conclude, that the pigment varieties are correlated with the geographical distribution, the North Sea and Channel forms being predominantly pale, the Bay of Biscay form dark, but I am not certain, that this conclusion would be sound. In any case, the point may be left for discussion until the data both from the northern waters and the Mediterranean have been more closely analysed.

Remarks. In the further discussion of the different forms of *A. laterna*, it is necessary to consider adult and postlarval specimens together and it is convenient to begin with the northern forms. The material consists of the earlier collections made by the "Thor" in the years 1904—1906 in all waters

from the Kattegat to the west coast of Ireland and Bay of Biscay. The adult material has been obtained from the Channel (Plymouth) and the North Sea (Holland and Denmark).

We may endeavour first of all to correlate the pigmentation and length on metamorphosis of the postlarval specimens with number of caudal vertebrae and depth of water.

a. North Sea: *A. laterna* var. *microstoma*, forma *communis;* pale form of postlarva predominant. Southern North Sea (S. of 54° N.L.): length on metamorphosis 16 mm. (formaline specimens); about 130 pelagic specimens in 4 hauls (August—September 1906); 33 adult specimens from Helder, Holland.

	27	28	29	30
87 post. specimens	1	19	53	14
33 adult —	1	10	19	3
120 —	2	29	72	17

Eastern North Sea (Danish coast); length on metamorphosis 18—20 mm. (formaline): 49 pelagic specimens in 4 hauls (September 1904).

28	29	30	31
10	35	3	1

The pelagic specimen with 31 caudal vertebrae was 24 mm. in length and quite symmetrical. It thus seems quite out of place among the others, which have all metamorphosed by 20 mm.

In 17 postlarval and adult specimens taken near Heligoland, Ehrenbaum (1897), who also gives ca. 16—18 mm. as the length on metamorphosis, found

28	29
2	15

In 1 postlarval specimen (dark pigment) from the Kattegat I found 30 caudal vertebrae and in 20 adult specimens from the same region

28	29	30
1	14	5

whilst Dr. Johansen has kindly given me the following data from this own observations on the Kattegat form.

28	29	30
2	17	16

It thus appears, that there is a shifting of the centre of balance in the North Sea region alone as we go from south to north, i. e. from shallow to deeper water. The average number of vertebrae is distinctly higher in the Kattegat than in the North Sea, whilst the length on metamorphosis is greater off the Danish than off the Dutch coast.

Among all these pelagic specimens from the North Sea region — and also many more in which the vertebrae were not counted — I have only found two which might be called abnormal. These were, firstly, the 24 mm. long specimen with 31 caudal vertebrae taken off the west coast of Denmark in September 1904. This was quite symmetrical; it had very little pigment on the body, but the spots on the tail and otocystic region characteristic of the Biscay form (see later) were present. The second specimen was only 15 mm. long with 30 caudal vertebrae, taken in the Kattegat in September 1906; its black pigment was very conspicuous. It should be mentioned, however, that Petersen (1909) figures a postlarval specimen of *A. laterna* from the North Sea, which has considerably more black pigment than is usual in the North Sea form and further, that in preserved material from Heligoland, which Prof. Ehrenbaum kindly lent me, I also found one specimen with a considerable amount of black pigment. Thus, even in the North Sea region the pigment may be very variable, but whether present in small quantity or large, its distribution is quite different from that in *A. Thori* (= *A. Grohmanni* auct.), as can readily be seen from the figures on Plates I and II.

b. Channel: *A. laterna* var. *microstoma* forma *communis*; pale form of postlarva predominant.

Metamorphosis: 33 postlarval specimens between 20 and 26·5 mm.; of these 5 between 20 and 23 mm. (Straits of Dover and Mounts Bay) metamorphosed; 4 at 24 mm. and 1 at 26·5 mm. also metamorphosed; all the others (i. e. 24 specimens) in various degrees of metamorphosing, but not yet metamorphosed, 1 not even at 26 mm. Owing to this later metamorphosis the Channel form is on the whole larger, i. e. broader or deeper as well as longer, than the North Sea form.

The transition is at once remarked when we compare a series of samples from the Dutch coast southwards through the Channel. For example, at St. 198 (1906) in the Channel (just W. of 0°) the specimens are beginning metamorphosis at 24—26 mm. whereas only about 3—400 miles eastwards (St. 200) they are in the same stage at 16 mm. The boundary is not so very sharp, however; thus, the Channel form is present at St. 100 in the North Sea (off the Thames), whilst at St. 161 (just west of Dover) the metamorphosed specimens of 20—22 mm. resemble more the North Sea form, as also the metamorphosed specimens of 21—22 mm. taken in Mounts Bay in Cornwall. Thus, so far as the length on metamorphosis is concerned, the specimens of the Channel are somewhat mixed.

Number of caudal vertebrae:

	28	29	30	31
75 postlarval specimens	6	34	30	5
49 adult specimens (Plymouth)	·	10	32	7
	6	44	62	12

Whilst the adult specimens consist of a homogeneous unit, the postlarval specimens strengthen the impression gained above, that the Channel form is somewhat mixed. A closer analysis of the data, to determine, for example, whether the smaller length on metamorphosis is associated with lower number of vertebrae and whether there is really a segregation of two distinct forms in the Channel, is unfortunately impossible in this case, as the great majority of the postlarval specimens were taken out over deep water all over the Channel. We are thus referred to the judgment we can obtain from a comparison of the Channel form with the North Sea form on the one hand and the Bay of Biscay form on the other.

So far as the pigmentation is concerned, the Channel specimens belong to the pale form, thus the same as the North Sea specimens. For example, 24 specimens ranging from 10—17 mm. in length were taken at St. 163 off the Bill of Portland; these were indistinguishable from North Sea specimens of the same size, so far as the pigment and form are concerned. It is naturally only after these sizes that we get the "large" form of the Channel. The number of caudal vertebrae in these 24 specimens was, however, as follows: 29—9, 30—14, 31—1, thus quite different from the formula for the North Sea specimens.

c. South of Ireland.

I have examined 6 postlarval specimens from south of Ireland (St. 186, 1906), varying in length from 17.5 to 24.5 mm., the largest with metamorphosis almost complete, the others symmetrical; number of caudal vertebrae: 1 at 29, 3 at 31, 2 at 32. In pigmentation these all belonged to the pale form.

d. Bay of Biscay: *A. laterna* var. *microstoma*, forma *biscayensis*; dark form of postlarva predominant.

Metamorphosis: 48 pelagic specimens examined in all; of these 6 below 20 mm., 20 between 20 and 25.5 mm., 20 between 26 and 29.5 mm., 1 of 30.5 and 1 of 32 mm. All those below 20 mm. and most below 26 mm. were quite symmetrical; in some metamorphosis beginning at 23 mm. All those between 26 and 30 mm. in varying degrees of metamorphosis; 1 at 26, 1 at 28, 1 at 29 and the 2 specimens over 30 mm. had just completed metamorphosis.

The pigment in most is abundant and conspicuous (Pl. II figs. 19—21) but in a few there is only a little pigment and one of 24 mm. resembles in every way the 24 mm. specimen mentioned above as taken off the west coast of Denmark.

This large, well-pigmented postlarva is the form that PETERSEN (1909) suggested, might belong to "*A. Grohmanni*" (*A. Thori*). How different it is from the true *A. Thori*, however, can be seen at once from a comparison of the figures on Plates I and II, as also from the number of caudal vertebrae. As shown above, *A. Thori* has usually 28 or 29 (p. 61), in the present postlarval form we have usually 30—31.

If we only knew the two postlarval forms, the pale, small form ot the North Sea metamorphosing at 16—20 mm. and this large, dark form of the Bay of Biscay metamorphosing at 26—30 mm., we should agree fully with PETERSEN, that they must certainly belong to two different species. The difficulty on this interpretation arises, when we bring the Channel and Irish forms into the comparison.

The most remarkable fact about these postlarval specimens from the Bay of Biscay has still to be mentioned. Whilst all the other collections, North Sea, Kattegat, Channel, S. of Ireland, were made in August and September, most of the Biscay specimens were taken in the month of May 1906.

	27	28	29	30	31	32
North Sea (185 spec.)	2	41	121	20	1	
Kattegat (56 —)		3	31	22		
Channel (124 —)		6	44	62	12	
S. of Ireland (6 —)			1		3	2
Bay of Biscay (48 —)			4	21	22	1
	2	50	201	125	48	3

It will be of advantage if we now summarise the data so far as we have gone. Including the data of EHRENBAUM for the North Sea and of JOHANSEN for the Kattegat, we have the accompanying picture for the number of caudal vertebrae.

It can be readily seen from this table, that we have to deal with at least 3 if not 4 distinct groups in regard to the number of vertebrae and we can test the probability of the reality of these different groups by means of mathematical formulae. Following the methods pursued in my earlier paper (1900a), I have calculated the standard deviation or index of variability[1] of the different groups and the probable fluctuation of the average, assuming, that is, that each group may be considered for present purposes as a homogeneous and constant unit. The results are shown in the following table.

Region	No. of spec.	Average no. of caudal vertebrae	Standard deviation	Probable fluctuation of average
North Sea	185	28·87	·67	28·72—29·02
Kattegat	56	29·34	·57	29·09—29·59
Channel	124	29·65	·96	29·35—29·95
Bay of Biscay	48	30·42	·79	30·07—30·77

The conclusions to be drawn from this table seem quite clear. In the first place, we have at least 3 well-marked groups or races of *A. laterna* in northern waters, for however many samples of, say, 100 to 200 specimens we may examine from the North Sea, taking them of course at random, the chances are all against our finding any sample with more than 29 as the average number of caudal vertebrae and it is equally certain, that Kattegat and Channel samples will not have less than 29 as the average, whilst the samples from the Bay of Biscay will never have less than 30. Put in another way, 1 sample in a 1000 of North Sea specimens may have the average at 29 or just above, but not one sample in a million would have 30 as the average number of caudal vertebrae. In the second place, the variability is much greater in the Channel specimens than in the others and least in the Kattegat specimens.

The imperfections of the material, absence of adult specimens from the Bay of Biscay, absence of postlarval specimens from the Kattegat, smallness of the samples etc., cannot seriously affect these main conclusions, as they are allowed for in estimating the probability. For example, we have in reality 4 samples from the North Sea alone and it will be noticed that in all 4 samples (adults from Helder, postlarval specimens from Southern North Sea and from Eastern North Sea and EHRENBAUM's specimens)

[1] See DAVENPORT — Statistical Methods 1899; HEINCKE und EHRENBAUM — Eier und Larven von Fischen der deutschen Bucht II, 1899; DUNCKER — Die Methode der Variationsstatistik, 1899.

the average is below 29 caudal vertebrae; again, in two samples from the Kattegat, which differ considerably from one another, the average in both is above 29 caudal vertebrae; lastly, we may say we have two samples from the Channel, one of postlarval specimens, the other of adults, and though these two samples again differ somewhat from one another, yet in both the average number of caudal vertebrae is above 29·5. Further, though not shown, the sample from the Bay of Biscay is in reality composed of 3 smaller samples, each of which, like the sample from S. of Ireland noted above, gives more than 30 for the average number of caudal vertebrae. We might of course estimate the error in each sample separately and thence calculate the average error for the different regions, by the method shown in a previous paper, but the net result would be the same, since the principal assumption is the same, namely, that each region contains a homogeneous or fairly homogeneous group, constant from year to year and our aim is simply, to compare the characters of the groups in the different regions. The mathematical analysis has shown, that on this assumption the different groups are or can be distinguished from one another. The proof of the assumption is another matter; for this we should require continuous material over a number of years, but it is in any case simply the ordinary assumption underlying all systematic work, namely, that the characters of a species or group remain constant from year to year within fairly restricted limits.

It is of interest to enquire now, whether the data and results are compatible with the possibility, that we may be dealing with 2 distinct species, the one a shallow-water species belonging essentially to the North Sea but extending southwards along the narrower zone of shallow water in the Channel and possibly further, the other a deep-water species belonging essentially to the Bay of Biscay and south of Ireland, but with offshoots in the Channel, west of England and possibly further north. From the analysis of the adult characteristics in the genus *Arnoglossus* (pp. 29—33), we are also at liberty to conclude, that these 2 "species" are indistinguishable in the adult stages, so far as dimensions are concerned. Hence the specific characters would have to be found in the number of vertebrae (and fin-rays) and in the postlarval characteristics. The main characters of the "species" would then be:

α. communis: caudal vertebrae 27—30, mainly 28 and 29; metamorphosing between 16 and 20 mm.; postlarvae with little pigment as a rule.

β. biscayensis: caudal vertebrae 29—32, mainly 30 and 31; metamorphosing between 26 and 30 mm.; postlarvae with abundant pigment as a rule.

It seems to me, that there are formidable objections to such a conclusion. In the first place, the Channel specimens cannot be regarded as a simple mixture of two such species. If we combine the data for the North Sea and Bay of Biscay, by converting the frequencies into percentages, we should have the following combinations.

28	29	30	31	32	
11	37	28	23	1	for 100 specimens
5	19	14	12		for 50 specimens

But in 49 adult specimens from Plymouth we have found 10, 32 and 7 for 29, 30 and 31 vertebrae respectively and in the total number of specimens from the Channel (converting the frequencies into percentages).

28	29	30	31
4	36	50	10

Nor is it possible by any increase in the proportions of the Biscay form (2 to 1, 3 to 1 or 4 to 1 etc.) to obtain such a combination of the two "species" as would approximately agree with the data for the Channel.

Again, if the Channel form is a mixture of two such species, we should expect, that the metamorphosing specimens would fall naturally into two distinct groups, one of 16—20 mm. in length, the other

of 26—30 mm. in length. It would be desirable certainly, to have a larger material of metamorphosing specimens from the Channel, but such as it is, it shows distinctly, that the Channel specimens metamorphose between 20 and 27 mm., thus at a length *intermediate* between the two "species".

Lastly, there is the difference between the North Sea form and the Kattegat form.

Altogether, it seems to me, that the available material will not permit of the conclusion, that *A. laterna* in northern waters consists of 2 (and only 2) "species". In the beginning, I arranged the material in the belief, that it would be possible to make a clear separation between these species and in the tables showing the records of the Mediterranean cruises of the "Thor" (pp. 16—21) it will be noticed, that I still retain the results of the attempted separation. Comparison of the adult forms and of the adult characteristics in the genus *Arnoglossus*, however, combined with the above analysis and an analysis of the Mediterranean forms, to be given below, has compelled me, to give up the 2 "species" hypothesis.

The available material suggests rather, that *A. laterna* is an exceedingly variable species, one which possesses a great adaptability to very diverse conditions. We obtain the picture of a species which lives on the boundary between shallow and deep water, adapting itself to one or the other according to the environment. And we can even discern the laws or mode of its adaptation. From a study of the genus as a whole (as also of the parallel genus *Pleuronectes*) it is seen, that *A. laterna*, whether as one or two species, stands in the middle of a series, which extends from very shallow out to deep water, which begins with a low number of caudal vertebrae (23) and continues through intermediate links to a high number (35) and which has a varying length on metamorphosis from 14 up to 50 mm. The rule is, the greater the depth of water, the greater the length on metamorphosis and the higher the number of vertebrae. These correlations have been firmly established and to complete the picture we have only to add, that the greater the length on metamorphosis means necessarily the longer the pelagic life. Just as ontogeny recapitulates phylogeny, so *A. laterna*, the middle of the series structurally as well as biologically, is a more concentrated grouping of the widely fluctuating characters of the genus; on the one hand, it is a close copy of the 2 smaller species, on the other it tends to fall over into the characters of the 2 larger species, wherever the conditions permit. By contrast with the other species, its composition is thus more fluent or pliable and we find it living under more widely varying conditions.

On this view each region has its own separate stock with definite and permanent characteristics generation after generation. The Southern North Sea has its own stock of the smaller form, the Channel has an intermediate form and as the conditions of depth are more diverse there we find, that this Channel form is more variable than the others, shown for example in the index of variability; the Bay of Biscay has also its own stock. If immigration takes places from one region to another during the postlarval stages and it is not likely to occur except in these stages, the migration will mostly concern the larger form with longer pelagic life and greater size on metamorphosis, since, presumably, the smaller form will not be carried pelagically such a long time or such a long distance. Hence, for example, if there is any immigration from the North Sea into the Kattegat, the immigrants will be composed of the longer individuals with the higher number of vertebrae, so that the natural stock of the Kattegat is increased by the larger individuals and not by the small; the average number of vertebrae in the Kattegat form would thus be on the whole higher than in the North Sea form. This may explain the higher average in the Kattegat, though of course the explanation is not really necessary. Again, the symmetrical postlarval specimen of 24 mm. in length with 31 caudal vertebrae, which was taken off the west coast of Denmark in September 1904, was clearly an immigrant, whether from the Channel or round the North of Scotland we cannot say, but so far as we know there is very little interchange between the Channel and the North Sea. If the Channel receives any of the smaller form from the North Sea, these are counterbalanced by arrivals of the large form from S. of Ireland, though probably not from the Bay of Biscay, as the direction of the currents there is southwards. On the whole, however, I do not believe, that any

of the regions owes much to immigration, the perils of the sea are too great, but it is certainly worthy of note, that if individuals of the large southern form should wander into the North Sea, they can be easily detected and we thus have in them a ready index of the presence of southern or Atlantic water.

With regard to the pigmentation of the Biscay specimens, it does not seem, that we can attach much importance, from a systematic standpoint, to the fact, that the great majority have copious black pigment, whereas in the North Sea and Channel forms the pigment is not conspicuous. In the first place, one and the same sample from the Bay of Biscay contains several pale specimens among a number of dark and in the second place, as already mentioned, dark specimens may also occur in the North Sea samples. Though the pigment is thus not of specific importance here, it is yet possible that within this species the dark pigment may be associated with a higher number of vertebrae. This point, however, is perhaps better discussed in connection with the Mediterranean specimens.

A more important fact in connection with the Bay of Biscay specimens is, that most of them were taken in the beginning of May (1906). A few (12 specimens) were also taken in September at the northern entrance to the Bay (St. 194, 1906). These latter were all small (5—7 mm. long) and "all characterised by well-developed pigment" (PETERSEN 1909), whereas the great majority of the former were over 20 mm., though 4 lay between 8 and 12 mm., and other 6 were less than 20 mm. As explanation of this peculiar occurrence PETERSEN suggests, that the pelagic life may be very prolonged, even throughout the winter, This suggestion seems to me very probable, but the discussion of this question may also be postponed, until we have considered the Mediterranean specimens and what is known regarding the spawning period.

Before considering the Mediterranean specimens, I may just briefly summarise the results with regard to other characters of the northern forms. The number of caudal vertebrae is undoubtedly the principal character, but the others are of interest as affording corroborative evidence. We may take the number of fin-rays first of all; the numbers refer to the adult and postlarval specimens together.

D.

	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
North Sea .. (85 spec.)	1	1	6	8	15	11	17	12	9	4						1[1]	
Kattegat .... (13 spec.)					1	1	2	5	2	1		1					
Channel .... (93 spec.)				1	2	2	6	15	18	16	16	11	3	2	1		
Biscay ..... (43 spec.)								2	2	2	8	11	6	6	4	1	1
(234 spec.)	1	1	6	9	18	14	25	34	31	23	24	23	9	8	5	2	1

A.

	63	64	65	66	67	68	69	70	71	72	73	74	75
North Sea .. (85 spec.)	5	10	12	17	21	15	2	2					1[1]
Kattegat .... (13 spec.)				4	3	4	1	1					
Channel .... (93 spec.)	1			1	5	16	22	19	14	7	4	2	2
Biscay ..... (43 spec.)					1	2	4	9	9	6	7	5	
(234 spec.)	6	10	12	22	30	37	29	31	23	13	11	7	3

The variation in the number of fin-rays from region to region repeats again, naturally, the shifting of the balance which has been discussed above under the caudal vertebrae. By weighting the frequencies in proportion to the total numbers from each region or by converting them into percentages, the shifting would become even more prominent, but as I am not engaged in a theoretical discussion, the data as they stand sufficiently illustrate the facts. It is apparent here also, that the Kattegat and Channel specimens occupy an intermediate position between the North Sea and Bay of Biscay specimens and, further, that the variability of the different forms, as shown by the spread of the frequencies, is greatest in the case of the Channel specimens.

[1] It need hardly be said, that this is the specimen referred to above with 31 caudal vertebrae.

With regard to dimensional characters, I need only give the data for the proportions of the head, upper orbit and mouth, all of mature specimens. The other characters have already been discussed in dealing with the characters of the genus and we know already, that it can only be in the length of the head and mouth, that we need expect to find differences. Here I have only data for the Kattegat, North Sea and Channel. I am thus obliged to suppose, that the dimensions of the Bay of Biscay form agree with those of the Channel form.

Length of the head in proportion to the total length

	16	17	18	19	20 %
North Sea (30 spec.)	1	4	19	5	1
Kattegat.. (13 spec.)		2	7	3	1
Channel.. (47 spec.)		1	25	17	4
(90 spec.)	1	7	51	25	6

aver. 18·3 %

Length of mandible in proportion to length of head

	50	51	52	53	54	55	56	57	58	59 %
North Sea (30 spec.)		1	3	3	5	6	9	3		
Kattegat.. (13 spec.)			1		3	3	3	1	1	1
Channel.. (47 spec.)	2		3	9	7	10	12	2	2	
(90 spec.)	2	1	7	12	15	19	24	6	3	1

aver. 54·7 %

Length of premaxilla in proportion to length of head

	33	34	35	36	37	38	39	40	41	42 %
North Sea (30 spec.)			1	2	4	6	5	4	7	1
Kattegat.. (12 spec.)	1	1	1	2	2	3	2			
Channel.. (45 spec.)		1	3	10	9	8	3	9	2	
(87 spec.)	1	2	5	14	15	17	10	13	9	1

aver. 38·0 %

Longitudinal diameter of upper orbit in proportion to length of head

	31	32	33	34	35	36	37	38
Channel (42 specimens)	3	5	3	7	6	11	4	3

aver. 34·7 %

A brief comparison may be made first of all with the corresponding dimensions for *A. Thori*. Taking the averages only (cf. pp. 59—60) we have the following differences.

	A. Thori	*A. laterna* var. *microstoma*
Length of head / Total length	19·5 %	18·3 %
Mandible / Head	51·3 -	54·7 -
Premaxilla / Head	33·0 -	36·0 -
Upper orbit / Head	36·7 -	34·7 -

When expressed in this way, the differences between *A. Thori* and *A. laterna* are quite considerable, but there are two main reasons, why we cannot draw certain conclusions from the data. In the first place, the spread of the frequencies overlaps in all cases in the two species, and the material is not sufficiently large in the case of *A. Thori*. In the second place, the material of the latter species has far more smaller specimens than that for *A. laterna;* hence the head is relatively larger, with the consequence that the other dimensions are correspondingly smaller. On the whole, I think that two conclusions may be drawn; firstly, that the mouth in *A. laterna* is slightly larger than in *A. Thori*; secondly and with greater certainty, the upper orbit is longer than the premaxilla in *A. Thori*, whilst the reverse is the case in *A. laterna*.

With regard again to the differences in the above dimensions for the different groups or samples of *A. laterna*, when we consider the heterogeneous nature of the material, large and small specimens, males and females together, it is not possible to conclude anything from the small apparent differences between the samples; each sample might well be a selection from one homogeneous group with the varying frequencies of the total.

In addition to the above characters I have also examined the scales in the material from the different regions. In 6 specimens from Holland the number of scales along the lateral line amounted to

12—14 + 35—38 and the vertical series 11—12/12—13. In 7 Plymouth specimens the variation was greater: 13—15 + 38—44 (mostly 40) and 12/13.

So far as the year-rings or zones of growth on the scales are concerned, I have examined 20 specimens from the North Sea and another 20 from the Channel, but I am not convinced, that the results are quite reliable. In most cases it is quite a simple matter to detect the rings in the outer part of the scale — they are very distinct there — the difficulty is, that the scales appear to shrink or become more compact with growth or age, so that the rings first formed, especially of the first year, become indistinct. Of course, it may be, that there is no cessation of the growth during the winter of the first 2 (or 3) years in some specimens. In these cases, therefore, we have nothing to go by except the breadth of the 1st zone. Another point is, that the scales may be lost and regrown under natural conditions. Such regrown scales can always be known, I believe, from the fact, that their central region, instead of being formed of concentric rings like the normal scales, contains a more or less broad zone of granular substance with the concentric rings and radiating lines further out towards the margin. In such cases one, two or more growth-zones may be wanting, and I have always examined 6 to 10 scales from each fish to get over this difficulty, taking always the maximum number of rings found.

20 *A. laterna* from Holland, November 1912.

Size and sex.	No. of rings	Size and sex.	No. of rings	Size and sex.	No. of rings
5 cm.	0	12 cm. ♀	2	13 cm. ♀	2
6 —	0	12 — ♂	2	13 — ♂	2
10 — ♂	1	12 — ♀	1	14 — ♀	2
10 — ♂	1	12 — ♂	2	14 — ♂	2
10 — ♂	1	13 — ♂	2	14 — ♀	2
10 — ♂	1	13 — ♀	2	14 — ♂	4
10 — ♂	1	13 — ♂	2		

20 *A. laterna* from Plymouth, May—June 1912.

Size and sex.	No. of rings	Size and sex.	No. of rings	Size and sex.	No. of rings
5 cm.	1	11 cm. ♂	3 (4)	13 cm. ♂	4
6 —	(0) 1	11 — ♂	1 (2)	13 — ♂	4 (5)
6 —	(0) 1	12 — ♀	3 (4)	14 — ♀	4
8 — ♀	2	13 — ♂	2	14 — ♀	(3) 4
8 — ♂	1	13 — ♂	3	14 — ♂	5 (6)
9 — ♀	2	13 — ♂	3	14 — ♀	10—13
10 — ♀	2	13 — ♀	4		

It will be seen, that a number of irregularities occur in both tables, though more among the Plymouth data. Both indicate, that the growth in the first year certainly amounts to 6 cm. and may be 8 cm. At the end of the second year the length varies between 8 and 13 cm.; after the second year there seems little further growth or none and one specimen from Plymouth appears to be "aged" already at 14 cm. According to my records both the males and females are mature between 8 and 9 cm., thus certainly in the beginning of their 3rd year and some already perhaps at the beginning of their 2nd.

With regard to the maximum size reached by *A. laterna*, I may mention, that my largest specimen is 16·6 cm., a male taken in the Kattegat. Altogether, my material contains 11 male specimens between 14 and the largest size and 7 females between these sizes. None of these large males had the first dorsal rays elongated as in *A. imperialis*. It may be recalled, that Cunningham, Holt and Calderwood maintained, that these dorsal rays became elongated in *A. laterna* (their "*lophotes*" form) after 13 cm. had been reached and to explain away the fact, that the males may be ripe before the elongation of the fin-rays takes place, Cunningham put forward the analogy, that "a man's beard does not fully develop until long after puberty".

Mediterranean specimens. I have purposely refrained from bringing the Mediterranean into the above discussion of the northern forms of *A. laterna* for obvious reasons. The northern *laterna* is divisible into at least 3 local or geographical races; the Mediterranean *laterna*, as will be shown, may also contain 3 forms. It does not follow, however, that the 3 northern races are the same as the 3 southern forms; on the contrary, if the above interpretation of the northern races is correct, we can hardly expect the southern to be precisely the same. Hence the necessity of dealing with them separately.

The material of the Mediterranean forms of *A. laterna* is naturally far from being so satisfactory as that for the northern forms. I have only 20 specimens altogether of the adult form (immature and mature specimens), but the remarkable thing is, that these 20 specimens should be shared almost equally by two forms, the characters of which, had they been present in 2 of the northern races, would have justified us in considering them as 2 distinct species. As already indicated, however, one of these Mediterranean forms is indistinguishable from the northern races or rather, its adult characteristics fall within the range of variation of the northern races. The characters of the second adult form are distinct not only from those of the northern forms but also from those of all other species of the genus yet known. Inasmuch as we must, from a systematic standpoint, lay most stress on the adult characteristics, I think it right to regard these two forms as the principal divisions within the species and therefore call them varieties, meaning therewith, that they come nearer to distinct species than the other forms. The latter display local variations in the number of vertebrae and fin-rays and length on metamorphosis and may be called local races.

The discussion of the Mediterranean specimens should begin properly with these adult varieties and in the tables below a summary is given of the principal characters.

A. laterna var. *microstoma*				*A. laterna* var. *macrostoma*			
Total length	head / length	mandible / head	premaxilla / head	Total length	head / length	mandible / head	premaxilla / head
43 mm.	21 %	56 %	36 %				
58 —	20 -	55 -	38 -				
72 —	18 -	53 -	37 -	81 mm.	21 %	59 %	44 %
76 —	18 -	50 -	36 -	83 —	22 -	62 -	43 -
80 —	19 -	54 -	36 -	89 —	21 -	61 -	42 -
83 —	20 -	53 -	34 -	91 —	21 -	62 -	41 -
83 —	18 -	55 -	37 -	93 —	22 -	61 -	46 -
86 —	20 -	53 -	35 -	100 —	22 -	63 -	45 -
90 —	20 -	52 -	39 -	114 —	21 -	63 -	46 -
92 —	20 -	58 -	39 -	130 —	20 -	66 -	47 -
93 —	19 -	52 -	39 -	130 —	21 -	67 -	46 -

It is apparent, that there is a wide difference between the two varieties in these characters. The difference would be even more marked if the sizes in the two groups had been more equal; for, as has been shown in an earlier paper (1900 a), the relative size of the head decreases with age or growth. However, the difference in the head is not the most conspicuous difference, as the following data show.

head / length %		18	19	20	21	22
	var. *microstoma*	3	2	5	1	
	macrostoma			1	5	3
		3	2	6	6	3

mandible / head %		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
	var. *microstoma*	1		2	3	1	2	1		1									
	macrostoma										1		2	2	2			1	1

premaxilla / head %		34	35	36	37	38	39	40	41	42	43	44	45	46	47
	var. *microstoma*	1	1	3	2	1	3								
	macrostoma								1	1	1	1	1	3	1

Thus, the principal difference lies in the size of the mouth. When it is remembered, further, that the head is also slightly larger in the large-mouthed form, it follows that the absolute size of the mouth must in reality be greater than the above relative comparison allows to be seen. The absolute sizes have already been compared (p. 33) for different total lengths (taking northern specimens for the larger sizes), but the difference may be shown in another way, by multiplying the frequencies for *macrostoma* by the ratio of the averages for the head (ca. 21/19). Thus we find, that by comparison with the length of the head in variety *microstoma* the length of the mandible is between 53—54 % in *microstoma*, but ca. 70 % in *macrostoma* and the length of the premaxilla between 36 and 37 % in *microstoma*, but nearly 49 % in *macrostoma*. These differences in the size of the mouth are appreciable to the naked eye (text-fig. 2, p. 33).

In spite of these obvious differences and in spite of the fact, that they may be taken as permanent, since CANESTRINI found the same difference in these characters as long ago as 1861, I do not feel justified in raising *macrostoma* to the rank of species on the basis of this evidence. It is possible, namely, that the intermediate stages may be just as numerous as the two extremes here investigated, so that a very much larger material must be examined. If such a material proves, that the two extremes remain permanently separated, then the name *macrostoma* is the most appropriate for the large-mouthed form, since it would distinguish this species not only from the common *laterna*, but also from the other species of *Arnoglossus* yet known. My specimens of *macrostoma* have been taken at Banyuls in the south of France, Naples and at the "Thor" station 142 to the east of Malta; further, CANESTRINI stated, that *macrostoma* was common in the Gulf of Genoa[1].

	Caudal vertebrae		
		29	30
var. *microstoma*		9	2
macrostoma		9	

	Dorsal rays							
	86	87	88	89	90	91	92	93
var. *microstoma*					3	4	3	1
macrostoma	1	2		2	1	3		

	Anal rays							
	65	66	67	68	69	70	71	72
var. *microstoma*		1	1	1	1	3	3	1
macrostoma	1		1	4	3			

The number of caudal vertebrae and fin-rays in the two varieties is shown in the following summary.

These results agree with CANESTRINI's data, but obviously give no safe basis for the separation of two species and just as little for the separation of postlarval specimens.

When we turn now to the postlarval specimens of *A. laterna* taken by the "Thor" on its Mediterranean cruises, we find that we must leave the variety *macrostoma* practically out of account. The postlarval specimens can be divided fairly easily into two groups according to the pigment, a pale and a dark form, but as both these forms occur in northern waters, we cannot ascribe the parentage of either of them to *macrostoma*. Owing to its larger mouth we might imagine by analogy with other genera that *macrostoma* lived mainly in shallower water than *microstoma* and thus might metamorphose at a smaller size. But the reasoning would be unsound; in the first place, we know that the common small-mouthed *laterna* lives in quite shallow water; in the second place, St. 142 at which the "Thor" dredged up 2 specimens of *macrostoma*, had a depth of 98 meters. Further, though this is not good evidence, the material from the Mediterranean contains no metamorphosing or metamorphosed specimens of *A. laterna* under 20 mm., the size below which, by analogy with the North Sea form, we might expect *macrostoma* to metamorphose. Hence, since the number of vertebrae and fin-rays give no basis for the separation of the varieties and

[1] 6 specimens from the Oceanographical Museum of Monaco belonged to the variety *microstoma*.

the small difference in the size of the mouth cannot be noticed in the postlarval specimens, I am unable to say, whether the variety *macrostoma* can be distinguished from the other forms in the postlarval stages.

As mentioned above, the postlarval specimens from the Mediterranean can be divided into two groups by means of the pigment. This can be done with comparative ease and though I feel sure, that these groups are merely colour variations of one and the same species, just as in the case of the northern forms (see above), I think it useful to retain the distinction throughout the following discussion. They are also distinguished in the main tables, and in the chart showing the distribution.

The total number of specimens of *A. laterna* taken by pelagic nets in the Mediterranean (including the stations in the vicinity of the Straits of Gibraltar) amounted to 240; of these 200 belonged to the pale form and 40 to the dark; in addition, 10 others belonging to the dark form were taken along the coast of Portugal. The characteristics of these two forms have already been described (cf. figs. Pl. II) and it only remains to see, whether in other ways they are related to or show any parallel with the northern forms.

The principal character chosen to display the variation of the northern races was the number of caudal vertebrae and for the sake of comparison I have selected the largest of the Mediterranean specimens and counted the number of caudal vertebrae, with the following result.

	28	29	30	31
A. pale form	1	21	9	1
B. dark form		7	17	6

Thus, there is quite an appreciable difference between the two forms, but it will be noticed, that we cannot well ascribe either of them to the variety *macrostoma*. There is in reality a closer parallel with the northern races, the pale form coming near to the Kattegat race, whilst the dark form is intermediate between the Channel and the Biscay races. In neither case, however, is there a precise correspondence. The Biscay race, for example, has an average of about 30·4 caudal vertebrae, here the average for the dark form is below 30. These differences confirm the view obtained from the northern forms, that *A. laterna* is an extremely variable species, which assumes different racial characters in every region in which it occurs. The dark and pale forms of the Mediterranean cannot be referred to any of the northern races; they are independent races and if we add to these the variety *macrostoma* we see, that the Mediterranean may contain 3 different races. My material cannot be expected to be representative of these races; as a matter of fact, the Mediterranean samples only touch upon the fringe of the local distribution in each case. It is possible, that the conditions are more uniform in the Mediterranean than in the northern waters, but it is more probable, that each locality or area has its own special race. For example, the dark form of postlarva occurs mainly in the Western Mediterranean and along the adjacent coasts of the Atlantic (see Chart annexed), but 5 specimens with well-marked pigment were taken in the Sea of Marmora. So far as one can judge, these 5 specimens belonged to the same type as the former, but a larger material may show, that the Marmora race has quite a different average number of caudal vertebrae, just as the dark form of the Western Mediterranean differs from that of the Bay of Biscay.

The number of dorsal and anal rays was also counted in several specimens and the results may be noted.

D.

	83	84	85	86	87	88	89	90	91	92	93	94	95	96
A. pale form	1	1				2	3	6	2	2	1			
B. dark form								2	1	4		3	1	3

A.

	63	64	65	66	67	68	69	70	71	72	73	74
A. pale form	1		2	4	4	2	1	3		1		
B. dark form						1	2	2	2	4	1	2

That the variation in the number of fin-rays merely follows that of the number of caudal vertebrae, requires no comment.

With regard to the length on metamorphosis, my material contains 9 specimens of the pale form, which in-

dicate very approximately at what length it metamorphoses; 4 at 18 mm. are just at the beginning of metamorphosis, judged by the slight reduction in the forward point of the supraoccipital spine, though still quite symmetrical; 3 at 20 and 1 at 21 mm. (see fig. 17) represent a slightly more advanced stage and 1 at 22 mm. lastly (see fig. 18) has evidently just metamorphosed. With regard to the dark form 1 specimen of 24 mm. is in process of metamorphosis (see fig. 21).

We thus have again here the same correlation as we found in the northern waters, namely, pale form with smaller number of caudal vertebrae and smaller length on metamorphosis; dark form with higher number of caudal vertebrae and greater length on metamorphosis. Whether the final term in the series of correlations holds good, i. e. depth of water during the pelagic life, is not so readily determined from the data for the Mediterranean. And in any case it has to be remembered, that so far as the pigment is concerned, the correlation is not absolute, the pale forms of the Channel and South of Ireland metamorphosing also at a length between 24 and 30 mm.

Spawning-period. The spawning period of *A. laterna* in northern waters is supposed to be from May to August and to explain the occurrence of large postlarval specimens in the beginning of May Petersen has suggested, that these may live pelagically throughout the winter. It is of interest, to investigate what the present material can show with regard to these points.

In the first place, the adult material received from northern waters is quite in accordance with a spawning-period in the summer. All the specimens from Holland received in November and those from Plymouth received in May-June had spawned, whilst some from Plymouth in February were preparing to spawn. On the other hand, one adult female of 130 mm. taken in November at Naples was full of ripe or nearly ripe eggs. Further, Holt (1899) found the pelagic eggs at Marseilles in March and we have it from Graeffe (1888), that *A. laterna*, which "bildet den Hauptbestandtheil der sogenannten "Minutaglia" in Triest", spawns there in December and January.

With regard to the postlarval specimens, all the northern collections agree with a spawning-period in early summer or summer, with exception of the Biscay specimens taken in May. But it may be noted, that early larvae were also taken in the Bay of Biscay in the month of September and further, that no investigations have been made in October or November and very few and scattered in the winter months.

The Mediterranean specimens may be divided into two groups, below 10 mm. and 18 mm. and above, and considered month by month. We then have the following results, the numbers in the table representing specimens.

		June	July	August	September	February
A. pale form	< 10 mm.	4	124	13		
B. dark form	< 10 mm.	23		4		2
A. pale form	18 mm. +		5	4		
B. dark form	18 mm. +	2			1	1

The numbers are greatly affected, naturally, by the amount of fishing in the different months and the regions visited. Thus, in June and September the "Thor" was working mostly at the western end of the Mediterranean and in the Atlantic. Nevertheless, the results are for the most part in agreement with a principal spawning-period for both forms in April to August. But it will be noticed, that two small larvae occurred in February and a third specimen of the dark form, 13·5 mm., was also taken in that month. These 3 specimens were probably spawned not earlier than November. Add to these the ripe adult specimen taken in November at Naples as also Graeffe's and Holt's statements and we see, that some specimens of *A. laterna* may spawn at the end or the beginning of the year, in the winter, and that the paucity of the records is rather due to lack of investigations. The large number of specimens taken in May in the Bay of Biscay is in agreement with this view. The question, whether one form or race may spawn mainly at a different time from the others, requires further investigation.

Distribution. *A. laterna* occurs in the coastal waters of Europe from the Kattegat and Christiania Fjord southwards into the Mediterranean as far as the Sea of Marmora. It has not yet been recorded, curiously enough, from the east coast of Scotland.

The vertical distribution of *A. laterna* ranges from about 10 meters out to 60 as a rule, but both small and large specimens have been taken beyond 60 m. The "Thor" has taken 6 specimens at 98 m. in the Mediterranean, St. 142 east of Malta, so that it possibly lives at even greater depths.

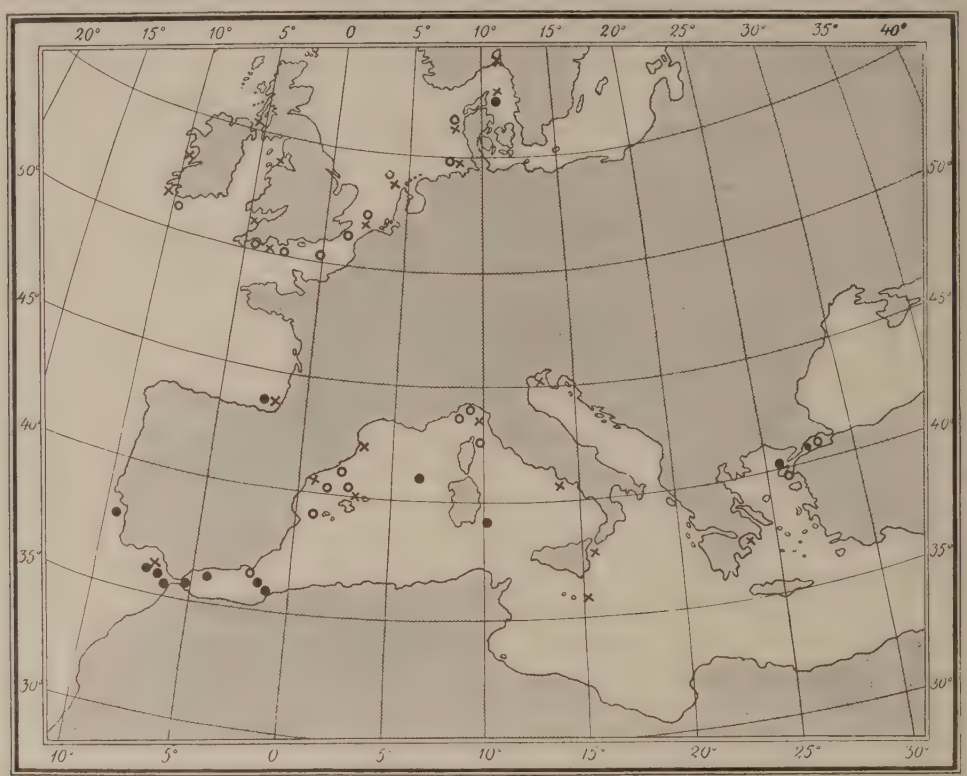


Chart 3. Distribution of *Arnoglossus laterna* sens. lat.
× = Known occurrence of adults.
○ = Pale form of postlarva.
● = Well-pigmented form of postlarva. } Records of the "Thor".

The distribution of the pelagic stages is of interest in this connection, and in the following table I give the number of specimens taken by the "Thor" over the different depths, in the same manner as for *A. Thori* (see p. 63).

Depth at stations	0—100	100—500	500—1000	1000—2000	> 2000
No. of specimens	129	11	42	48	20

Thus, out of 250 specimens 68 or about 27 % were taken over depths greater than 1000 meters and another 17 % over depths between 500 and 1000 meters. The fact that the "Thor" fished more over these depths naturally affects the percentages, but it seems fairly certain, that unless the metamorphosed specimens can live at great depths (1 metamorphosing specimen of 21 mm. was taken over more than 2000 meters) a very large proportion must perish. The pelagic specimens live as a rule near the surface, 10—40 meters, but at St. 122 45 specimens were taken in the net fishing with 600 meters wire out, thus at about 400 meters, over 1285 meters.

ARNOGLOSSUS IMPERIALIS (Raf.)

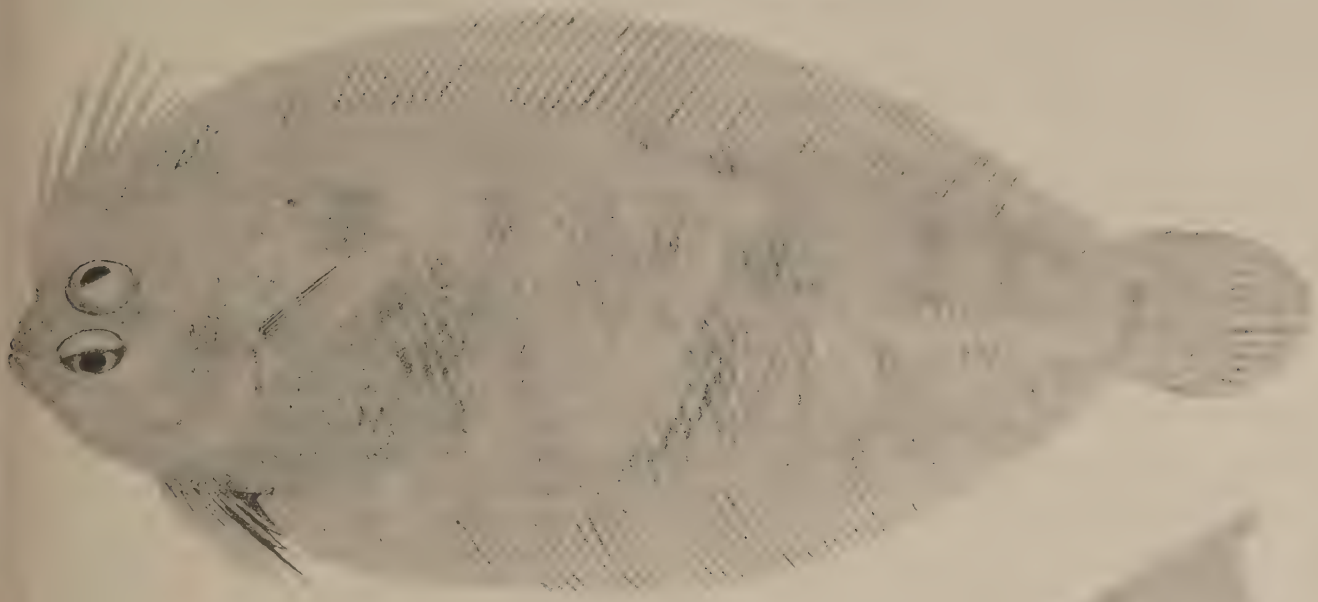


Fig. 10. Adult ♂ of *A. imperialis*, Plymouth. n. s.

Bothus imperialis Rafinesque-Schmalz, 1910.
? *Pleuronectes casurus* Hanmer in Pennant 1812.
Arnoglossus lophotes Günther 1862, 1890.
— *laterna* Cunningham 1890; Holt and Calderwood 1895.
— *lophotes* Collett 1896.

Postlarval stages:
Charybdia rhomboidichthys Facciolà 1885.
Arnoglossus lophotes Petersen 1909.

Fig. 10 a.
Adult ♀; head. Plymouth.

D. 94—(96—101)—105; A. 74—(76—79)—82; P. (9)10—11/10; V. 6/6; C. 17; Vert. 10 + 32—(33)—35 = 42—(43)—45. Scales 14/15; 16—17 + 44—47 = 62.

Adult characteristics; Habit pyriform pointed in front; scales deciduous. By comparison with total length (including tail) the greatest height is 33·5 %, length of caudal fin 16 %, length of head 17—18 %. By comparison with the greatest height the distance of the greatest height from the caudal fin is ca. 145 %. Height of caudal peduncle 49—50 % of length of tail. By comparison with the head the length of the left mandible is 51—53 %, the longitudinal diameter of upper orbit 36—38 %, left premaxilla 32—34 %; thus, the orbit is greater than the premaxilla (compare *A. Thori* and *A. laterna*). Colour dark gray to brown with darker patches.

Secondary sexual differences: The 2nd to 5th (6th) dorsal rays in the mature male much elongated, free in most of their length, thick and fleshy; longest ray (3, 4) 15—17 % of total length of fish or nearly of equal length with the head; left ventral also slightly longer in the male than in the female, the 3rd and 4th rays being 9—10 % of total length of fish, where in the female they are only 7—8 %. In the mature female the 2nd to 5th dorsal rays are also slightly elongated, free at the ends and fleshy, but

the longest is only 8—10 % of the total length or about half the length of the head; further, they are not so thick as in the male. On the left ventral the males have a conspicuous black marking spread over the membrane from the 4th ray backwards; in the female there is only a faint trace of this marking, but it is more of a grayish colour and little distinguished from the ground colour of the body and fins.

Spawning period; spring. Length at first maturity probably 13—14 cm.

Metamorphosis: This takes place between 30 and 50 mm.; one specimen at 29·5 mm. is beginning metamorphosis, another at 30 mm. has just completed metamorphosis, whilst 2 specimens of about 48 mm., which I consider belong to this species, were still symmetrical[1].

Postlarval characteristics: These are in every way a recapitulation of the characters of *A. Thori* (q. v.), but on a larger scale. The postanal bar of pigment spreads out on to the fins between the rays D (72) 74—80 (82) and A (52)53—59(60); in the earliest postlarval stages when it is still on the body of the fish, this postanal bar lies over the (22)23—26 caudal vertebrae (fig. 22); in the position of the postanal bar we thus have a ready means of distinguishing this species at all stages from *A. Thori*, the only species with which it might be confused. When metamorphosis takes place, this postanal bar still remains as the most prominent and largest of the bars on the fins and interspinous regions (fig. 11). The black chromatophores on the anal and abdominal regions (including the air-bladder) are also very prominent and in greater number than in any other species of *Arnoglossus*; as metamorphosis approaches, these gradually diminish in size and finally disappear at the same time as the air-bladder disappears and the abdomen becomes closed below (fig. 26). The rows of black chromatophores along the proximal portion of the dorsal and anal interspinal regions are most conspicuous halfway through postlarval development, but also disappear later. In the earliest stages, ca. 7 mm. (fig. 22), there is a small, black spot of pigment at the extreme, posterior end of the notochord[2]. In the living condition there is probably a lot of coloured pigment mixed with the black; in formaline specimens, this coloured pigment is orange or reddish brown, thus similar to what is found in *A. Thori.*

The distribution of the spines and spined plates in *A. imperialis* is very characteristic, being similar to that in *A. Thori* but on a somewhat larger scale (see pp. 42, 43 and fig. 25).

By means of the spines, especially those on the cartilaginous pubic bar, this species can be distinguished readily at all stages from 7 mm., before the fin-rays are differentiated, onwards until metamorphosis begins, from all other species of *Arnoglossus* with exception of *A. Thori*, from which it is distinguished by means of the number of fin-rays and vertebrae, as well as the position of the postanal pigment bar.

Remarks. *A. imperialis* was first discovered by Rafinesque in 1810. In 1862 it was redescribed by Günther under the name of *A. lophotes.* Day (1884), Cunningham (1890) and later Holt and Calderwood (1895) denied the separate existence of "*lophotes*", maintaining, that it was only the older stage of *A. laterna.* Collett (1896) revived "*lophotes*" but did not know Holt and Calderwood's work. Finally, Petersen (1909) definitely proved, that "*lophotes*" was a separate species, by describing a series of postlarval stages, which agreed in specific characters with this species and were quite distinct from those known of *A. laterna.* Since the postlarval and the mature stages are known to be distinct, it seems hardly necessary to discuss the reasoning by which Holt especially endeavoured to keep the two species as one. It need

[1] These two specimens belong to the Naturhistorisches Museum in Hamburg and were kindly lent me for examination by Prof. Pfeffer. With some others they formed the basis of his account of the osseous skeleton of the head in postlarval flat-fishes (1886, 1894). They were taken apparently in the surface-water of the North Atlantic.

[2] Holt (1900 a and b) has described eggs and larvæ which in all probability belong to this species. The eggs (taken from ripe females) measured ·75 to ·76 mm. with single oil-globule ·12—·13 mm. (*A. laterna* ·68—·69 mm.; o. g. ·14—·15 mm). Larva (referred to "*A. Grohmanni*") with pigment near the caudal extremity, thus as in *A. Thori.*

only be pointed out, that the main difficulty for HOLT still remains, namely, we do not yet know the young stages of this species. These may probably live in deeper water than the adults yet found; in any case, it is only a matter of searching for them.

My material of *A. imperialis* consists of 74 adult specimens (37 males and 37 females) between 15 and 20·5 cm. in length, obtained from Plymouth, and some 20 larval and postlarval specimens from 6 to 37 mm., embracing all stages of postlarval development.

The identity of the postlarval specimens with the adult can hardly be questioned. The *Arnoglossus* characteristics of the former are at once apparent from any of the figures and, as will be shown below, the number of vertebrae and fin-rays are the same as in the adult form. There might be a doubt, however, as to whether RAFINESQUE's name should be revived for this species. As already explained, however (p. 23), RAFINESQUE's description is in this case quite a good one and leaves no room for hesitation. To make this quite clear, I may quote the whole of it.

"*Bothus imperialis.* Almost three times longer than broad. Dorsal fin beginning in front of the eyes. Lateral line arched at the base, left side smooth, olive-green, shaded by dark gray, right side white, tail straight.

This species is called *Tappa Imperiali* or *Linguata Impiriali;* it is a better fish to eat than *Linguata* (*Citharus*?), but is rarely caught, as it always lives in the sandy or muddy depths of the sea, where it hides under the sand or mud; is very different from the preceding (*Bothus Tappa* = *A. Grohmanni* Bon.?), being larger and having the following number of fin-rays, namely, in the dorsal ca. 100, in the anal ca. 80 — — — —".

This definition agrees, as accurately as we could wish, considering the period, with the female specimens of the present species (compare diagnosis above).

Comparison of the number of vertebrae (caudal) and fin-rays in the postlarval and adult specimens gives the following results.

	32	33	34	35
Adults { males	8	22	6	1
Adults { females	7	26	4	
Postlarval specimens	1	12		
Total (87 specimens)	16	60	10	1

The whole range of variation is 4 vertebrae, practically however only 3, and the average is practically 33; for the males the average is exactly 33, for the females a fraction lower.

D.	94	95	96	97	98	99	100	101	102	103	104	105
Adults ♂			3	2	6	7	5	6	3	1	2	1
Adults ♀	1	1	4	9	6	6	6	2	1			
Postlarval specimens			1			2	3	1	1	1		
Total (81 specimens)	1	1	8	11	12	15	14	9	5	2	2	1

A.	74	75	76	77	78	79	80	81	82
Adults ♂	1		2	9	13	6	1	3	1
Adults ♀	1		7	11	8	6	3	1	
Postlarval specimens	1	1			2	2	1	1	
Total (81 specimens)	3	1	9	20	23	14	5	5	1

With regard to the fin-rays, it will be noticed, firstly, that the postlarval specimens agree with the adults and secondly, that here as with the caudal vertebrae the females have a slightly lower average number (about 1½ rays for D, nearly half a ray for A) than the males. The precise weight to be

attached to these differences between the males and females will depend, naturally, on whether the number of fin-rays is correlated with the number of vertebrae. The evidence from three series which vary together and in the same direction is of no more weight than the evidence from one of the series. It is thus mainly a question, whether the sample is large enough to show such a difference between the sexes; large though the material is, it is hardly large enough for this purpose. Further, if we look again at the series for the vertebrae, we see, that this sample has another peculiarity, namely, that the males are more variable than the females. This peculiarity also reappears in the series for the fin-rays, which strengthens the probability, that the difference found between the sexes is a peculiarity of this particular sample and not of the species. In calculating the amount of correlation between vertebrae and fin-rays, therefore, it is unnecessary to make any distinction between the sexes.

The total range of variation is for D. 94—105, for A. 74—82 or 12 and 9 rays respectively; over 50 %, however, are restricted to 3 rays in the case of D. 98, 99, 100, and 2 rays in the case of A. 77 and 78, and over 80 % to 6 rays in the case of D. 96—101, and only 4 rays in the case of A. 76—79. The predominant range of variation is thus restricted to a comparatively small number of rays and the sample is certainly large enough to be representative in this respect. It might even be thought, that the extremes (D. 94 and 105; A. 82) were somewhat improbable, but, as a matter of fact, such extreme cases are always counted several times, simply because they are so unusual, and thus certainly occur.

Some conception of the correlation between the number of vertebrae and fin-rays may be obtained from the following tables.

Vert.	D.												No.	Aver. of D.	A.									No.	Aver. of D.
	94	95	96	97	98	99	100	101	102	103	104	105			74	75	76	77	78	79	80	81	82		
32			4	2		5	3	1		1			16	98·6	1		4	3	5	2				15	77
33	1	1	4	7	11	8	10	6	4		1	1	54	99	1	1	4	14	15	10	4	4	1	54	78·1
34				2	1	2	1	2		1	1		10	100			1	3	3	2		1		10	78
35									1				1	(102)											
	1	1	8	11	12	15	14	9	5	2	2	1	81		2	1	9	20	23	14	4	5	1	79	

		D.												No.	Aver. of D.	Aver. of A.
		94	95	96	97	98	99	100	101	102	103	104	105			
A.	74			2				1						3	97·3	77·9
	75							1						1	100	
	76	1	1		4	1	2							9	97	
	77			3	4	3	3	1	4		1			19	98·6	
	78			2	1	7	7	3	1	2				23	98·8	
	79				1	1	2	7	1	1	1			14	99·9	
	80				1			1	1	1				4	100	
	81			1					2			1	1	5	101·4	
	82											1		1	104	
No.		1	1	8	11	12	14	14	9	4	2	2	1	79		
Aver. of A.		76	76	77	77·2	77·7	77·7	78·1	78·6	78·7	78	81·5	81			
Aver. of D.							99									

It will be seen, that the correlation, though not perfect, is yet as good as one wish for, considering the material. The number of fin-rays in both D and A show a decided, if not quite regular, increase

with the increase in the number of vertebrae. In the case of the fin-rays also there is a distinct positive correlation, most clearly seen, naturally, where the numbers are largest, e. g. between 96 and 102 and 76 and 81. It may be remarked, that the difference in the total numbers in the various series is due to several specimens being damaged in one or the other character.

The percentage dimensions given in the diagnosis for the various characters are the averages derived from a number of specimens. Thus, the statement that the caudal fin is 16 % of the total length is based on the measurements of 78 specimens. The range of variation is from 15 to 17 % with only one 18 %. It was formerly the custom (see GÜNTHER's Catalogue) to state the dimensions of the various parts of the fish in terms of the total length minus the tail fin. Except for very fine work, however, e. g. study of races, I find that this is unnecessary in the case of the flat-fishes. For example, in a group of 13 specimens the caudal fin was 8 times 16 %, 5 times 17 % of the total length including the caudal fin, but when the latter was deducted from the total length the percentages became: 1 at 18 %, 6 at 19 %, 4 at 20 % and 2 at 21 %. The greater variation in the latter case, which can be readily understood, is clearly of no advantage in stating the general proportions of the different characters. Other characters examined in the same way, e. g. head, height etc., gave naturally the same result.

The greatest height of the body (without D and A fins) lies a short distance behind the beginning of the straight part of the lateral line, about the 4th scale on the latter. The greatest height is naturally not restricted to one particular spot or line, for the slope of the dorsal profile reaches its highest point slightly behind that of the ventral. The spot indicated for the greatest height is thus rather the centre of an area about 1 cm. broad of the same height. In 73 specimens the variation in the greatest height, expressed in percentage of the total length, is shown by the following summary:

Length	♂						♀								♀ + ♂	
	32	33	34	35	No.	Aver.	31	32	33	34	35	36	No.	Aver.	No.	Aver.
151—160 mm.....	..	..	1	..	1	34	..	1	..	..	2	..	3	34	4	34
161—170 —	1	..	2	..	3	33·3	..	1	4	2	2	1	10	33·8	13	33·8
171—180 —	..	4	7	1	12	33·7	1	1	6	5	2	..	15	33·4	27	33·5
181—190 —	1	6	5	4	16	33·7	..	1	2	4	..	..	7	33·4	23	33·7
over 191 —	2	1	1	..	4	32·7	2	..	..	..	..	..	2	31	6	32·2
	4	11	16	5	36	33·6	3	4	12	11	6	1	37	33·4	73	33·5

The males are most numerous at the greatest lengths; there was one male over 200 mm. (204). So far, however, from the fish increasing in height the longer they are, it would rather appear as if the height diminished. This would tend, therefore, to make the difference between the males and females even greater than the averages indicate. Though the sample is too small for much weight to be attached to this difference, it is certainly worth while pointing out the fact, and also the other curious fact, that the males are on the whole larger, though not necessarily older, than the females.

I have counted the number of scales in a vertical series and longitudinally in 10 specimens. In the vertical series the numbers were usually 14/15, 13 occurring twice in the upper and 14 once in the lower half. Longitudinally 17 was the usual number for the pectoral arch with a variation of 45—47 in the straight part of the lateral line.

The age or growth has also been investigated by means of the scales; occasionally also the opercular bones, especially the suboperculum, were used to assist in the determination. But the determinations are nevertheless not quite certain. The difficulties are the same here as in the case of *A. laterna*. The outer rings are very clear and distinct, but the situation of the 1st winter ring is a matter more or

less of guess-work. And we do not have here, as in the case of *A. laterna*, the younger specimens which could give some indication of the breadth of the first and second zones.

150 mm.	2	rings	(both scales and bones)
155 —	5	—	(scales)
180 —	4	—	(scales and bones)
180 —	5	—	(—)
182 —	(4)5	—	(scales and bones)
182 —	4	—	(—)
185 —	3	—	(—)
185 —	(3)4	—	(—)
190 —	4	—	(—)
200 —	6	—	(scales and bones)

By comparison with *A. laterna* and *A. Thori*, it thus appears in general, that *A. imperialis* grows much faster during the first 2 to 3 years at any rate. The above specimens were taken in the winter time and if we take 13—15 cm. as the size at first-maturity, we see that *A. imperialis* probably becomes mature at the beginning of its third year. In *A. Thori* and *A. laterna* maturity was reached already at a much smaller size and sometimes at the beginning of the second year.

	♂					♀					♂+♀	
	17	18	19	No.	Aver.	17	18	19	No.	Aver.	No.	Aver.
151—160 mm.....	..	1	..	1	18	..	2	1	3	18·3	4	18·2
161—170 —	..	3	..	3	18	2	7	1	10	17·9	13	17·9
171—180 —	2	11	..	13	17·8	6	9	..	15	17.6	28	17·72
181—190 —	7	7	2	16	17·7	3	4	..	7	17·57	23	17·66
over 190 —	2	2	..	4	17·5	2	..	..	2	17	6	17·7
	11	24	2	37	17·8	13	22	2	37	17·6	74	17·7

The relation between length of head and total length of fish is remarkably constant, as one would expect. The total range of variation in both sexes is only 17—19 %, and the average is 17·7 %. Where a character such as the head can be measured with very great accuracy, it is of interest to inquire, whether even such a comparatively small material as the present can display any difference between the sexes and different sizes. The above table has been prepared in the same way as the corresponding one for the greatest height.

It is impossible to attach great weight to these results, but nevertheless, it is noteworthy, that in this material the relative length of the head gradually decreases at the greatest lengths in both sexes and the females have a slightly smaller head than the males. The fact, that the females are on an average smaller than the males, accentuates this latter difference.

In connection with the head we have the three important characters: size of the eye, maxilla or premaxilla and mandible. Instead of the eye, which does not lend itself to exact measurement, the longitudinal diameter of the upper orbit is taken here. The following tables show the variation in each of these dimensions, expressed in percentages of the length of the head.

Left mandible:

	♂									♀										
	49	50	51	52	53	54	55	No.	Aver.	48	49	50	51	52	53	54	55	56	57	No.	Aver.
151—160 mm.....	..	..	..	..	..	..	1	1	55	..		1		1	1		..	..	..	3	51·7
161—170 —	..	..	1	1	1	..	..	3	52	1		3		3	1		2	..	..	10	51·7
171—180 —	..	3	1	5	4	..	..	13	51·8	..		4		6	3		1	..	1	15	52·2
181—190 —	..	4	..	8	3	1	..	16	51·8	1		1		1	2		1	1	..	7	52·4
over 190 —	1	..	2	..	1	..	..	4	51	..		..		1	..		1	..	..	2	53·5
	1	7	4	14	9	1	1	37	51·8	2		9		12	7		5	1	1	37	52·1

Total average (74) 51·97 %.

Premaxilla:

	♂										♀									
	29	30	31	32	33	34	35	36	No.	Aver.	29	30	31	32	33	34	35	36	No.	Aver.
151—160 mm	..	..	..	..	..	..	..	1	1	36	..	..	..	..	1	2	..	..	3	33·6
161—170 —	..	1	..	1	..	1	..	..	3	32	1	..	..	..	4	4	1	..	10	33·2
171—180 —	..	..	4	1	6	2	..	..	13	32·5	..	1	..	3	6	3	2	..	15	33·1
181—190 —	1	..	2	3	4	3	3	..	16	32·9	..	3	1	1	..	1	..	1	7	32·1
over 190 —	..	..	2	..	2	..	..	..	4	32	..	..	..	..	1	1	..	..	2	33·5
	1	1	8	5	12	6	3	1	37	32·6	1	4	1	4	12	11	3	1	37	32·9

Total average (74) 32·8 %.

Upper orbit:

	♂									♀									
	35	36	37	38	39	40	41	No.	Aver.	35	36	37	38	39	40	41	No.	Aver.
151—160 mm	..	1	..	..	..	..	..	1	36	..	1	2	..	..	..	..	3	36·7
161—170 —	..	..	2	..	..	..	1	3	38	..	1	..	7	..	1	..	9	38
171—180 —	1	..	9	..	3	..	..	13	37·3	4	2	5	1	1	2	..	15	36·9
181—190 —	2	3	4	3	3	..	..	15	37·1	1	..	1	..	4	..	1	7	38·4
over 190 —	..	1	1	..	1	1	..	4	38	..	1	1	..	..	..	..	3	36·5
	3	5	16	3	7	1	1	36	37·4	5	5	9	8	5	3	1	36	37·4

Total average (72) 37·4 %.

It is evident from the wide range of variation and the irregular distribution of the frequencies, that the available material does not lend itself to such a detailed analysis as the above. The mandible is certainly capable of very exact measurement, the premaxilla also to a great extent, but a great dispersion of the frequencies for the orbit would not be surprising, as it is the most difficult dimension of the three to measure exactly. Nevertheless, we see, that the range of variation and dispersion of the frequencies is not any greater in the case of the orbit than the other two. We can therefore only conclude, that a very much larger material would be required to display regularity in the variation of these characters, that is, that they are naturally very variable within certain limits. In any case, any regular increase or decrease relative to the head cannot be concluded from these observations. It is more probable, that beyond a certain length the relative proportions of these dimensions remain practically constant, in both male and female.

With regard to a difference between the sexes, it would appear from this material, as if the females had a slightly larger mouth than the males, both mandible and premaxilla being slightly larger, but there is no difference in the size of the orbit.

The mandible is, absolutely, just a little more (2 %) than half the length of the head, the premaxilla is a trifle less than the third. Relative to one another, therefore, the premaxilla is about two-thirds (63 %) of the length of the mandible. It is of importance to note, also, that the premaxilla is distinctly smaller than the upper orbit's diameter (4·5 % by comparison with the length of the head). The same relation was found in *A. Thori*, whilst the reverse is the case in *A. laterna* (p. 72).

The pectoral fins show no appreciable sexual differences. The left pectoral is considerably longer than the right as usual, the former varying between 12 and 15 % of the total length, the latter between 6 and 8 %. The number of rays is also invariably greater in the left than in the right pectoral. In the former we find usually 10 long, branched rays with a short, simple ray uppermost; in about 30 % of the cases 9 instead of 10 occurred and 11 also occurred a few times; sometimes the short ray was absent. In the right pectoral 9 long rays were more frequent than 10.

The differences in the ventral fins of the two sexes have already been noted above; a curious thing is, that as with the elongated dorsal rays the elongated ventral rays in the mature male become thick and fleshy by comparison with the corresponding rays in the female.

Distribution. *Arnoglossus imperialis* certainly occurs from south of the Azores (L'Hirondelle; COLLETT 1896) to the north of Scotland, in the western basin of the Mediterranean but, apparently, not very far into the eastern. The adults are common in 60—70 meters at the western mouth of the English Channel and not rare south and south-west of Ireland, but do not appear to penetrate into the southern half of the North Sea. Such a well-marked form would hardly have escaped notice in this well-fished region and its postlarval stages are not present in the rich collections of the "Thor" from the North Sea. On the other hand, it has been taken by the "Thor" in the northern parts of the North Sea between Scotland and the Orkneys (PETERSEN 1909) and will thus probably be found on the Norwegian coast.

The following table summarises the captures made by the "Thor" on its Mediterranean cruises.

Locality	Alboran Sea and off Algierian coast	S. E. of Sardinia	Off Algierian coast and Alboran Sea	Bay of Biscay	Channel	E. of Sicily	Tyrrhenian Sea	Off Algierian coast
Month of capture	June	July	September			December	January	February
Number of specimens	3	1	3	3	3	1	1	2
Size in mm.	8, 8·5, 10	7	6·5, 11, 11·5	29, 29, 30	9, 9, 9	7·5	18	29·5	6·5, 7
Depth at Station m.	1150—2800	602	200—350	182	100	112	> 2100	> 1800	> 2000
Approx. depth of capt.	20—40	0—20	0—20	40—100	40	40	0—20	40	200

Chart 4. Distribution of *R. imperialis* (Raf.).
× = Known occurrence of adults.
○ = Postlarval specimens taken by the "Thor".

In adition to the above, 10 specimens have also been taken by the "Thor" in earlier years, 9 in 1906 from the Channel and west therefrom off the Bay of Biscay and 1 from the Pentland Firth 1905, all taken in the month of September and the size ranging from 15·5 to 35·5 mm.

Reviewing the above table, we see, that the small specimens occur in practically every month in which investigations were made, whilst the large are most abundant in September; one large specimen occurs in Jan-

uary. According to HOLT, as noted above, the spawning period should be in spring, and with this agrees the large number of the large specimens (11 altogether including the earlier) taken in September. But the occurrence of small specimens in February, as well as of a large specimen in January, would indicate, that here just as in the case of *A. Thori* and *A. laterna* we have to deal with an indefinitely prolonged spawning-period, with the main spawning in the spring. The presence of both small and large specimens over very deep water points to both a prolonged postlarval life and also to a deep-water habitat.

The records of the occurrence of this species are noted on the accompanying Chart.

5. ARNOGLOSSUS RÜPPELI (Cocco).

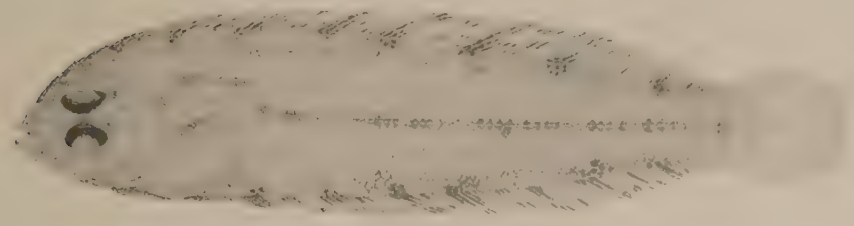


Fig. 11. Young specimen of *A. Rüppeli*, 41 mm. × 3.

Postlarval stages:

Peloria Rüppeli Cocco, 1844.
Bascanius tædifer Schiödte 1868.
Charybdia Rüppeli Facciolà 1885.

D. 110—116 (118?); A. 86—92; P. 10 + 1/10; V. 6/6; C. 17; Vert. 10 + 33 (34) 35 = 43 (44) 45; Scales: ca. 17 + 59 = 76.

The characteristic postlarval form to be described below has been taken previously at various places in the Mediterranean and North Atlantic. Though the anatomical structure reveals its parentage even at an early stage, its systematic position has hitherto been merely a matter of conjecture. COLLETT (1896) came nearest to the truth in suggesting, that it was perhaps an Arnoglossus or Lepidorhombus.

Remarks. The adult form is not known, at least it has not been described. In the case of such a deep-water fish, as this undoubtedly is, it is always possible, however, that the distribution is very extensive, if not cosmopolitan. As will be shown later, there is good reason to believe, that the Mediterranean and neighbouring parts of the Atlantic can by no means be regarded as the centre of distribution of the species. None of the Atlantic species described from the American side agree with the present form, so far as I have been able to see, but imperfect descriptions make a certain determination very difficult. JORDAN and GOSS (1889) suggest, that it may be connected with the form they call *Arnoglossus ventralis* from the Gulf of Mexico, described by GOODE and BEAN (1885), but even if the latter is an *Arnoglossus*, which is very doubtful, its fin-ray formula quite precludes its being the parent of the present form. In any case, there is no doubt, that our species is an *Arnoglossus* and as the name *Rüppeli* dates from 1844, it is not likely to require alteration.

The material contains 3 completely metamorphosed specimens of the species. Two, of 41 and 47 mm., have just completed metamorphosis (fig. 12) the third of 41 mm. shown above has evidently been metamorphosed for some little time. There is such a great difference in appearance between the last and the

other two specimens, that they might be thought to be different species, but the number of vertebrae and fin-rays, the latter being the more important character here, agree in all three cases.

The elongated form of these specimens as well as the high number of caudal vertebrae and fin-rays suggests, that the adults in their shape and structure diverge further along the lines indicated by *A. imperialis* by comparison with *A. Thori* and *laterna*. The habit would thus be more pyriform than in *A. imperialis*. This change of habit from oval to pyriform is found in the parallel series of species, *Pleuronectes flesus, platessa, microcephalus* and *cynoglossus*, with a very similar change in other characteristics, e. g. in the size of the head and mouth, number of vertebrae etc. and accompanied by the same gradual transition in habitat from shallow to deep water.

The *Arnoglossus* characters are clearly seen in the figure given above. The scales have evidently been present over the whole of the fish, but no scale is to be found in the specimen, even the lateral line, which is distinct on the eyed side but wanting on the blind side, being smooth; in other words, the scales are readily deciduous. Further, the left ventral advances forwards under the gill-cover, where the membrane uniting the gill-covers on each side is united across the isthmus below and extends into the fork of the urohyal. The last four abdominal vertebrae bear haemapophyses also. Lastly, it will be noticed, that the barred arrangement of the pigment on the fins and interspinous regions is precisely the same as in the other *Arnoglossus* species (comp. figs. 10, 11, 12, 18).

So far as the form is concerned, I may give the proportions found in the specimen represented in fig. 12 Plate I. It is probable, that the specimen figured above is extreme in regard to form. The third metamorphosed specimen is the same as the one to be described. The greatest height of the body is 28 % of the total length, the distance of the greatest height to the base of the caudal fin, measured along the lateral line, is 168 % of greatest height (145 % in *A. imperialis*), the head measured as in the preceding species 16 % of total length. The upper orbit is 39 % of the length of the head, the mandible 43 %, and the premaxilla 27 %; the latter is 62 % of the length of the mandible. For the sake of comparison, I may give the corresponding proportions of the head in *A. imperialis* at approximately the same stage. Length of head 17 % of the total length, upper orbit ca. 35 % ot the length of head, mandible ca. 51 %, premaxilla ca. 31 %. In the adult *A. imperialis*, as shown above, the proportions of the same dimensions are as follows: head 18 %, upper orbit 37 %, mandible 52 %, premaxilla 33 %. The differences in the relative dimensions of the parts of the head are thus not very great from metamorphosed specimen to adult stage, and the proportions given for the metamorphosed specimens of *A. Rüppeli* will probably agree fairly closely with those of the adult. In any case it appears, that the mouth is smaller in *A. Rüppeli* than in *A. imperialis*, thus indicating the further specialisation along the lines discussed above.

Whilst there can be no doubt, that the postlarval specimens dealt with really belong to the genus *Arnoglossus*, it might be questioned, whether they are the same species as Cocco's *Peloria Rüppeli*. As is well-known, Cocco regarded various pelagic, young fishes taken at Messina as distinct, adult species and later authors, for the sake of convenient reference presumably, have frequently mentioned them as separate species and genera (Bonaparte 1846, Facciolà 1885; see summary given by Jordan and Goss 1889; pp. 104—106). In 1885 Facciolà set up a special genus *Charybdia* for this and the preceding species, separating them from *Peloria* (the young of *Bothus podas*, see later).

If allowance is made for imperfect description on minor points, there can be no doubt, it seems to me, that the present species is the same as that described by the Italian authors. For the dorsal and anal fins Cocco gives D. 118, A. 90, Facciolà D. 113, A. 91. These fins reach to the root of the tail, which is separate, the long tentacle is present above the head and the left ventral is prolonged further in front than the right; further, one of Facciolà's specimens had the "Occhi piu o meno asimmetrici. Estremita anteriore della dorsale distaccata dal cranio". As shown above (p. 47), this is a fairly sufficient description of an *Arnoglossus* postlarva just on the point of metamorphosing, when the eyes begin to be a symmetrical

and the front part of the dorsal fin becomes detached from the ethmoid region. With this agrees the pigmentation; 9 bars of pigment are present on the dorsal fin and interspinous region and 8—9 similar bars on the anal fin and interspinous region[1] (comp. Plate I, fig. 12). The length of the specimen is stated to be between 30 and 40 mm.

Apart from the three metamorphosed specimens described above, my material contains 9 specimens from 7 up to 28 mm. in length in various stages of development. In fact, the series gives a practically complete picture of the postlarval history of this species. In many characters it differs so much from the other species of *Arnoglossus*, that there can be very little danger of confusing them, even in the earliest stage.

At 7 mm. (fig. 27) the larva is long and slender with a long tentacle extending more than half way along the dorsal fin and with a very faint indication of the interspinous regions dorsally and ventrally. As in the other species, the base of the tentacle at this stage is directly over the eyes and a few (2—3) spines can be detected there under the microscope, but none anywhere else on the body. The absence of spines on the abdomen thus differentiates *A. Räppeli* even at this stage from *A. imperialis*, the only other species with which it might be confused, for the broad postanal bar of pigment lies across the 21st or 22nd to 25th caudal myomeres, thus 3 to 4 vertebrae further back than in *A. laterna* or *Thori*. The liver is large, rectangular, filling almost the whole space from the clavicles back to the intestine. Below the liver anteriorly is seen a short, longitudinal streak of tissue, evidently the beginnings of the cartilaginous pubic bars, so characteristic of this and the next genus. The air-bladder is only faintly indicated above the coil of the intestine; it is evident, therefore, that we have here a very early stage in postlarval development. Apart from the absence of spines ventrally, this form is also distinguished by its pigment. The postanal bar, which stretches across the body, is not restricted to this however but extends out ventrally on to the anal, embryonic fin; further, it is broader ventrally than dorsally. Over the region of the air-bladder and coil of the intestine, there is a scattered group of large chromatophores, but there is no pigment on the rectum or near the anus. Nor is there any pigment in this specimen at the end of the notochord, which is quite straight, but this may occur, as a black chromatophore is present in some older specimens.

At 9 mm. (fig. 28) the dorsal and anal interspinous regions are clearly marked off along the body. The end of the notochord is still straight, however, thus giving the postlarva of this stage a somewhat pear-shaped appearance. A single row of spines (spined plates with 1 spine on each) is now present distally on the dorsal and anal interspinous regions, each spine being situated on the muscular tissue between each interspinous bone. Dorsally at the base of the tentacle and first D. ray the plates are more developed, each bearing 4—5 spines. Such plates are also richly developed ventrally just behind the foot of the clavicles, where the future ventrals will develop. There are no spines, however, along the pubic cartilaginous bar, which is now apparent more than halfway along the ventral margin of the liver. The air-bladder is now larger, lying under the 7th—8th abdominal vertebrae and the tentacle has grown forward and downward in front of the eyes. The pigment is essentially the same in position as in the earlier stage but is somewhat reduced in this specimen. Thus, in the abdominal region the chromatophores, of a pale to dark yellow colour, are concentrated on the air-bladder; there are none on the intestine, rectum or anus. The postanal bar is only apparent ventrally on the interspinous region and anal fin. There is a small black chromatophore at the end of the notochord. Here, as in the early stage, the distribution of the pigment together with the absence of spines on the abdomen and the less advanced state of development sufficiently differentiate this species from *A. imperialis*, whilst the position of the postanal bar clearly distinguishes it from the smaller species. The total number of vertebrae cannot be counted as yet, but it is clear, that there will be over 40.

[1] Some 8 to 9 spots of pigment are also stated to be present along the lateral line region. These may be chromatophores dorsal to the vertebral column.

At 12 mm. (fig. 29) the postlarval characteristics are fully formed. The end of the notochord has passed through the various stages of development very rapidly and is now completely enclosed. The number of caudal rays is 17 as in the other species, not 18 as stated by Cocco. The spinulation is more developed, there being 3 long spines on each interosseous space and a 4th at the end of the interspinous bone, decreasing from the middle of the interspinous regions posteriorly to one spine, with few as yet on the caudal fin, and increasing forwards to 5 or 6 on distinct plates at the base of each ray in the dorsal region over the head. The ventral fins are now apparent and at their base and round the foot of the clavicles there is a dense cluster of large spines, which are spreading up obliquely on to the liver; but there are no spines on the cartilaginous pubic bar under the liver. The pigment is essentially as before and the vertebrae and fin-rays can be counted; vertebrae 10 + 35, the spines of the last 2—4 caudal vertebrae not being formed as yet, D. 116, A. 90, the postanal bar of pigment lying at A. 61 to 64.

By 16 mm. (fig. 30) the spinulation has spread all round the body, there being now a single row of plates with one spine on each proximally across the caudal fin between each ray. Posteriorly on the interspinous regions of the dorsal and anal fins there are 2 to 3 rows of single spines, united further forward into one single spined plate bearing 4—5 spines and here and there a loose, single spine. There is a dense accumulation of these spined plates along the first interhaemal bone behind the rectum and another accumulation at the base of the clavicles and ventrals, spreading up obliquely on to the liver. The liver is now distinctly tongue-shaped, the pointed end projecting along the pubic bar below the intestine. The horizontal branch of the left pubic bone has now grown forward slightly in front of the foot of the clavicles and the rays of the ventrals, though short, are quite free. Here as in the earlier stage it can be seen, that the haemal and neural "spines" of the 2nd, 3rd and 4th last caudal vertebrae are broad and cartilaginous and take part in supporting the base of the caudal fin; in other words, they are really ural elements. The pigment is slightly different in this specimen, 2 large chromatophores being present between the 81st and 83rd rays of the dorsal fin to represent the dorsal part of the postanal bar, whilst the ventral part is comparatively well-developed, extending over 6 rays (61—66) of the anal fin with a large chromatophore opposite on the interspinous region. Further, there is a single, wandering chromatophore on the anal fin between the 31st and 32nd rays. It is evident, that the pigment is as variable in this species as in the others and to obtain a correct impression of it, we have to consider not one specimen only but the whole series. On the air-bladder, which is only moderate in size, lying below the 9th and adjacent parts of the 8th and 10th abdominal vertebrae, there is a diffuse yellowish pigment arising from a number of chromatophores each with a black centre; this pigment is only present on the eyed side. The tentacle has now grown forward and downward but has not yet reached to the ethmoid region. The mouth is comparatively small with a few large, scattered teeth. The number of caudal vertebrae is 34, of D. and A. rays 114 and 94 respectively.

So far as the form is concerned, the postlarvae remain practically in the same condition for a long time; they do not become relatively any longer or broader between 12 and 28 mm., the height measured across the abdomen without the dorsal fin being a little less than 50 % of the total length and narrowing abruptly behind the anus. The form is thus elongate and slender with a long tapering caudal region; further, the whole fish is very narrow and thin, presenting no appearance of solidity, such as we have seen is the case in the other species, particularly *A. Thori* and *A. imperialis*. During this period the changes of importance take place in the growth forward and downward of the anterior part of the dorsal fin, which, however, even at 22 mm. has not yet reached the ethmoid region; at this length the small, 1st dorsal ray is distinctly seen; further, in the growth and increase in number of the spined plates; at 22 mm. there are 3 to 4 rows on the tail, a double row along the interspinous regions and a further increase in the length and density of the spines at the places mentioned above. The pigment remains variable, sometimes a single or double chromatophore is present to mark the dorsal part of the postanal

bar, sometimes there is no pigment here at all and that on the air-bladder, which is greatly reduced at 22 mm., may also be reduced to a single chromatophore, but the ventral portion of the postanal bar always remains the most conspicuous part of the pigment.

At 28 mm. (fig. 31) the elegant slenderness of the body is still retained, but considerable changes have occurred otherwise. The supraoccipital spine above the eyes is much reduced, thus in process of resorption, and the anterior end of the dorsal fin is close to if not resting on the ethmoid region. The air-bladder has practically disappeared and the 1st interspinous bone is curving forward at the end. The base of the anal fin from the anus to the tail is thus more of a straight line than in the previous stage. These characteristics indicate, that the fish is just entering upon the last postlarval stage, but is still far from metamorphosis. The eyes are quite symmetrical, the left ventral has not yet grown forward to the urohyal and the ventral aspect of the abdomen is still far from being closed. In the latter region, in fact, the only effect as yet of the curving forward of the 1st interspinous bone has been, to make the rectum and intestine bulge out a little on the ventral line. The liver is still very large and tongue-shaped, though showing a distinct tendency to fold up at the tip.

The spinulation has now reached its greatest development (see scheme, p. 43). The base of the ventrals and lower half of the liver, but not the upper half nor the cartilaginous pubic bar, are now covered by a mass of spined plates, each bearing as a rule 5 to 6 spines. There are no spines on the intestine, but on the posterior margin of the rectum and running up from there along the 1st interspinous bone, there is another dense accumulation of spines, lower down in the form of spined plates, gradually changing further up to single spines. The distal ends of the interspinous regions of the dorsal and anal fins bear 2 rows of spined plates interosseously with frequently a single spine in addition. The caudal fin has 4—5 rows of spined plates. In addition, there is a new development of spines medially on the body, two rows along the vertebral column above and below, 2 to 3 single spines to each vertebra, and four similar, longitudinal rows dorsally and ventrally (see fig. 31). These rows run from the first caudal vertebra to the tail, decreasing towards the latter, so that only the 2 central rows remain on the last vertebra; forwards the vertebral and dorsal rows continue to the 3rd or 4th abdominal vertebra. There are no spines on the head proper or opercular apparatus. Such extensive spinulation is not known in any other postlarval form of fishes yet described, and from this character alone, we can say, that SCHIÖDTE's *Bascanius tædifer* belonged to this species.

The pigmentation has also undergone some change. There is no appreciable pigment in the region of the air-bladder and, naturally, none on the rectum. The postanal bar is represented by 3 chromatophores proximally on the anal fin between the 62nd and 64th rays, and by 2 chromatophores opposite on the dorsal fin between the 84th and 86th rays. In *A. imperialis*, it will be remembered (p. 80), the postanal bar lay between D. 74—80 and A. 53—59. In addition, there is now in *A. Rüppeli* a faint row of chromatophores along the base of the dorsal interspinous region, but no corresponding row on the anal interspinous region. The number of dorsal fin-rays is here 113, of anal 91 and of the vertebrae $10 \frac{5}{+} 34$.

It may be mentioned also, that at this stage the 4th last caudal vertebra has obtained definite haemal and neural, osseous spines, but the spines of the 2nd and 3rd last are still cartilaginous and support the base of the tail.

Between the postlarva of 28 mm. and the metamorphosed specimens of 41 mm. there is a gap in my material. It is not difficult to construct the intervening, metamorphosing stages, however, as these must be essentially the same as in the other *Arnoglossus* species. Further, there is also a connecting link in FACCIOLÀ's specimen "between 30 and 40 mm. long", which had the eyes asymmetrical and was thus in process of metamorphosis. This fits in well, as can be seen, with my series of specimens and the number of fin-rays given by FACCIOLÀ precludes his specimens being any other but the present species. It may

be said, therefore, that the postlarval history of this form, which has existed so long in the literature without home or parentage, is now fully known.

The vertebrae and fin-rays have been counted in 9 specimens. The abdominal vertebrae amounted to 10 in each case. The caudal vertebrae varied between 33 and 35, 1 at 33, 2 at 35 and 6 at 34. The average is thus 1 vertebra higher than in *A. imperialis*. The frequencies of the dorsal and anal fin-rays were as follows:

D.	110	111	112	113	114	115	116
	1		2	1	2	1	2

A.	86	87	88	89	90	91	92	93	94
	1		1	1	2	2	1		1

The range of variation agrees very well with that found in the other species of *Arnoglossus*. It is a point worth noting, that whereas an increase of 4 to 5 vertebrae in the other species (e. g. from *A. Thori* and *laterna* to *A. imperialis*) means a difference of only 10—12 fin-rays, here an increase of 1 vertebra means approximately the same difference in number of fin-rays, between *A. imperialis* and *A. Rüppeli*. The coordination between number of vertebrae and number of fin-rays, which has been shown to exist in the case of *A. imperialis* and which may be accepted as the general rule for all species, is obviously not an absolute one; that is, the degree of coordination for the species does not hold good for the genus. The difference in anatomical structure between *A. imperialis* and *A. Rüppeli*, which produces such a wide difference in number of rays corresponding to a difference of only 1 vertebra, consists simply in this, that more loose interspinous bones occur in the latter species, that is, 3 interspinous bones are inserted between 2 neural or haemal spines more frequently in *A. Rüppeli* than in *A. imperialis*.

Distribution. From the comparatively small number of specimens which have been taken by the "Thor", it would seem, that the Mediterranean and adjacent parts of the Atlantic are not the true home or centre of this species; at any rate, it cannot be said to be common here. The distribution in time and space of the specimens taken can be seen from the following summary.

Locality	60 miles S. of Minorca	S. E. of Sardinia	Gulf of Corinth	Messina	E. of Sardinia	N. of Majorca	Cape Gata	E. of Sicily	Middle of Ionian Sea	Off Naples	Off Algiers
Month of capture	June	July	August				Sept.	December		January	February
No. of specimens	1	1	1	1	1	1	1	2	1	1	1
Size in mm.	16	12	47	7	28	18	9	15, 22	41	41	18
Depth of stations m.	2800	600	842	>100	ca. 2700	>2000	>950	>2100	3700	560	1930
Approx. depth of capture } m.	0	0	800	0	200	200	0	40	200	100	50

The occurrence of specimens 12 and 16 mm. long in June and July, 7, 18 and 28 mm. in August, points to a spawning-time in spring and early summer, continuing, however, into the autumn as is indicated by the occurrence of the specimens 9 mm. in September, 15 and 22 mm. in December and 18 mm. in February. Taking the average, the specimens of 41 mm. taken in December and January might thus be about 6 months old, but it is evident, that the specimen of 47 mm. taken in August, which has just completed metamorphosis (fig. 12), could not have been spawned in the year of capture. The duration of the larval and postlarval life is thus certainly 6 months and may be a whole year. It is not possible to conclude more from this material, since there is always the danger with such a small number of specimens, that we are dealing with exceptional or extreme cases.

The occurrence of a specimen only 7 mm. long to the north of Messina would seem to make it certain, nevertheless, that this species spawns in the Mediterranean. To account for its presence there in

another manner, we should have to suppose, that some 4 months had elapsed since the egg was spawned, which is not very probable. Otherwise, there is nothing seriously opposed to the possibility, that the eggs and larvae of this species may be carried into the Mediterranean from the Atlantic. Thus, the specimen of 9 mm. taken in September not far from Cape Gata in the south of Spain may have been 2—3 months on the way, though, on the other hand, it may have come like the 7 mm. specimen from the middle of the western basin of the Mediterranean. It may be remarked also, that 4 specimens have been taken in the eastern basin, East of Sicily—Tunis, and one even in the Gulf of Corinth.

The possibility that these specimens have been carried in from the Atlantic depends, naturally, on the depth of water in which they live and it will be at once remarked as suggestive, that with exception

Chart 5. *A. Rüppeli* (Cocco).
○ = Postlarval specimens taken by the "Thor".

of one metamorphosed specimen all, including 2 metamorphosed specimens, have been taken in the surface layers and mostly out over the greatest depths. In such a case, given a sufficiently powerful Atlantic Current, and this is very certain, as also a prolonged larval and postlarval life, and this also seems certain, as shown above, the possibility of at least some of the specimens coming from the Atlantic cannot be excluded. On the other hand, if this does occur, then we are faced with the difficulty, that no specimens have been taken in the Atlantic north of Gibraltar. COLLETT's specimen was taken at the surface by "l'Hirondelle" to the south of Flores, Azores (St. 212). The specimen was 25 mm. long. SCHIÖDTE's "*Bascanius tædifer*" came simply from the "Atlantic".

The distribution of the specimens taken by the "Thor" is noted on the accompanying Chart.

B. Genus BOTHUS Rafinesque

Bothus Rafinesque-Schmalz 1810 (*rumolo* — female).
Solea — 1810 (*rhomboides* — male).
Bothus — 1814 (*diaphanus* — postlarval form).
Rhombus Cuvier 1817, Risso 1826, Canestrini 1861.
Bothus Bonaparte 1832, Steindachner 1868.
Platophrys Swainson 1839.
Rhomboidichthys Bleeker 1856, Günther 1862.
Platophrys Bleeker 1862, Jordan and Goss 1889 and recent authors.

This interesting genus, which is distributed all round the world in tropical and subtropical seas, has only one representative in European waters, *B. podas* (Delaroche 1809). One of the most remarkable peculiarities of the genus is, that the males differ widely from the females in the adult condition, so much so, that the two sexes more often than not have been described as distinct species. Partly for this reason the different species of the genus are very imperfectly known, and it will require no little time and patience to disentangle all the mass of names, which the genus has gradually come to harbour. What is more unfortunate is, that the characters of the "species", even the number of fin-rays, for example, are not given in the literature with trustworthy accuracy.

The European *B. podas* has long been well-known as a common Mediterranean species in its two forms, the male *Rhomboides* of Rondelet (erroneously called *mancus* by Risso, Günther and many authors) and the female *podas* of Delaroche. Steindachner, following up a suggestion of Costa, was the first to demonstrate, that the so-called *mancus* and *podas* were in reality one and the same species. From an examination of more than 40 specimens he found that those with the eyes wide apart were invariably males, those with the eyes by comparison near together always females. Further, by comparing smaller and larger specimens he was able to show, that even in the females the eyes move further apart during growth. Without knowing Steindachner's work, apparently, Emery (1886) has also made some few observations on this sexual dimorphism, but, on the whole, these interesting investigations have not received the attention they deserved. Even as late as 1881 *mancus* and *podas* are described separately by Moreau and in 1887 Facciolà still speaks of *mancus* as a European species. A collection of 42 specimens (22 males and 20 females) from various parts of the Mediterranean, obtained mostly however from Galita, Tunis ("Thor", Stat. 44), has enabled me to examine further into several interesting points of this sexual dimorphism. At the same time, since the separation of the other species of *Bothus* will be for a great part a study of variations, I have taken the opportunity to give a detailed account and diagnosis of the variation in this form, so far as the material permitted it.

It is of interest to note, that this difference between the sexes in this subfamily is in reality a variable generic or subfamily character and thus probably of comparatively recent origin in the history of the subfamily. Whilst in *Arnoglossus* the difference between the sexes is shown, when it appears at all, in a greater elongation of the rays of the dorsal and ventral fins, and nowhere else except perhaps in pigment, in the males, these characters have nothing to do with the sexual dimorphism in *Bothus*. In some species of this genus apparently, the left pectoral is more elongated in the male than in the female, but this is not the principal difference between the sexes, nor is it present, as will be shown, in the Mediterranean *B. podas*. The sexual dimorphism in this genus is principally displayed in the head region, the eyes being much further apart in the males, and various tubercles and rough ridges are well-developed, which are but little apparent or not present in the females. As will be shown, if the one character may be called a

secondary, sexual character, developing only with the beginning of sexual maturity, the other cannot be referred to this category, for they do not appear quite at the same size.

The late postlarval stages of *Bothus podas* have frequently been mentioned in the literature, chiefly under the name of *Peloria* (Cocco 1844, Bonaparte 1846, Facciolà 1885, etc.). As already pointed out, the principal difficulty in the way of identifying the parentage of these stages of *Bothus* arose from faulty observation. The same may be said also of Steenstrup's "*Plagusiae*", which undoubtedly belong here. Steenstrup (1864) referred his specimens to the "Plagusiae", because the dorsal, anal and caudal fins were supposed to be confluent, but a glance at his figures shows, that these fins were not confluent as in the so-called *Plagusia* (*Symphurus* etc.). A personal examination of his original specimens preserved in Copenhagen has also proved the correctness of his figures, and Steenstrup himself, in his later paper (1878), states that he would not be surprised, if his specimens proved to belong to one or other branch of the *Rhombus* family. His specimens came mostly from the western, a few from the eastern, parts of the Atlantic, and as a very large portion of my material has been collected in the same regions and in the same manner, it is not surprising, that precisely the same species have been obtained. Steenstrup also recognized, that his material contained at least 2 species (1878 p. 225).

Further, the "Challenger" obtained some 8 postlarval specimens of one of the species in Mid-Atlantic, which Günther (1889) merely describes as being like the pelagic "*Plagusiae*" of Steenstrup. Jordan and Goss also refer to some similar specimens taken in the western parts of the Atlantic, which they rightly refer to this genus, and it is fairly certain that Museums everywhere contain representatives. As will be shown, there should be not the slightest difficulty in referring these to the genus at any rate.

It is a different matter, however, with the younger stages, which differ in a remarkable manner from the older and might well give occasion for doubt and hesitation; these have not hitherto been identified and only once figured, to my knowledge. In his work on the pelagic fishes of the "Challenger", Günther gives a figure of a small postlarval fish of only 6 mm. in length, taken off the coast of Africa (Sierra Leone). No description is given, but the figure has the well-marked characteristics of *Bothus* (cf. text-fig. 13), and, judging from the place of capture, there can be little doubt, that it also belongs to the Mediterranean and Eastern Atlantic *B. podas.*

The presence in my material of a very large number of specimens, at all stages from the youngest to the metamorphosing and metamorphosed, leaves no room for doubt, that Emery (1883) was perfectly correct in his identification of "*Peloria*" with this genus. On the other hand, Facciolà's "*Rhomboidichthys mancus*" (1887) was an *Arnoglossus.*

The first to mention the later postlarval stages of *Bothus* was Rafinesque (1814) and his description contains a point of some interest, which I am not yet able to explain satisfactorily. His description reads: "*Bothus diaphanus.* Entièrement hyalin et diaphane, une tache rouge sur l'opercule, deux à la base de la queue et 12 autour du corps près des nageoires dorsale et anale, la dorsale commençant sur la bouche, ligne latérale droite. Observ. Espèce très singulière, longue d'une pouce et en travers de la quelle on peut lire."

In the first place, this description can apply to no other genus but *Bothus* (compare the figures given here of *Arnoglossus* and *Bothus*; a postlarval specimen of an *Arnoglossus* 25 mm. in length has black pigment; compare also diagnosis of the genus *Bothus* given by Rafinesque in 1810, as quoted above p. 10). The point of interest in the description is, however, the "taches rouges".

In 1826 Risso described his "*Rhombus candidissimus*" from specimens 60 mm. long, which Risso believed to be adults and stated to be full of eggs in May. What this species may have been is a mystery, but the remarkable point at present is, that the specimens also bore red pigment round the fins: "corpore candidissimo, rubro punctato". Again in 1885 Facciolà in redescribing Cocco's "*Peloria Heckelii*" states: "Il corpo e trasparente come cristallo, ornato di punti rossi sui lati e di una serie di circa 8 macchie dello stesso colore lungo la base della dorsale e dell'anale e due altre sulla radice della coda".

Assuming that the same species is referred to (and this is only doubtful in Risso's case), the accumulative evidence of these three observers, in spite of the manifest inaccuracies of each, should be a sufficient guarantee, that the postlarval specimens of the Mediterranean *Bothus* have red pigment. My formaline specimens (about 150 in number) from the Mediterranean, however, show no trace of this red pigment, nor do some 400 specimens of other species taken in the Atlantic. The conclusion would seem to be, that the red pigment of *Bothus* entirely disappears in formaline. As a rule, formaline is an excellent preservative of pigment, but no other conclusion seemed admissible. My astonishment was considerable, therefore, when the 550th specimen had this red pigment, in quantity and arrangement very much as described by the Italian authors. It came from the South Atlantic (20° 44′ S., 39° 53′ W.) and belongs to a different species from the Mediterranean *B. podas*. Two other specimens of *Bothus*, but probably of a different species, taken in the same haul were, like all other specimens I have seen, quite without pigment.

The single specimen with pigment restores one's faith in formaline, but it increases the mystery of the red pigment. The only explanation remaining would seem to be, that the pigment can only be seen in living, fresh and active specimens or in specimens, which are preserved at once. I do not regard this explanation as altogether satisfactory, but I feel obliged to accept the statements of the Italian authors, that the postlarval specimens of the Mediterranean *Bothus* have red pigment in the living condition.

Apart from the Mediterranean *B. podas*, the postlarval specimens of perhaps 3 other species of *Bothus* are present in the material. These have been collected in the surface waters of the Atlantic, mostly North Atlantic, by Danish ships plying between Europe and America. One of these species is represented by such a large number of specimens, that its specific characters (fin-ray formula and number of vertebrae) can be accurately determined. As it cannot be identified exactly with any species described by American authors I have called it simply *Bothus atlanticus*. It is the same species as the "*Plagusia*" of Steenstrup. The regional distribution of this species in the North Atlantic is complementary to that of *B. podas*, the latter extending westwards from Africa and Europe to a little beyond the Azores, the other continuing from there to America. The large number of different stations at which these two species have been taken in the Atlantic and Mediterranean will enable this interesting case of complementary distribution to be discussed in detail.

Of the other possible species only a few specimens are present in the material and until more have been obtained I need only refer to them. Of the 3 specimens taken in April 1912 in the South Atlantic, mentioned above, the pigmented specimen (19·5 mm. in length) had 26 caudal vertebrae; the other 2 were 12 and 14 mm. in length and had respectively 27 and 28 caudal vertebrae. If the conclusion stated above with regard to the pigment is correct, these specimens may belong to one and the same species, which, so far as one can judge from its mode of life, must be distributed over enormous areas out in mid-ocean. The other specimens which seem distinct from *B. atlanticus* and *B. podas* were taken in the North Atlantic not far from the coasts of the United States. They are distinguished from *B. atlanticus* by having a slightly higher average number of vertebrae. They will be further referred to under *B. atlanticus*.

Apart from the single specimen mentioned, a close comparison of the postlarval forms of all these possible species has failed to reveal any essential differences except in the number of fin-rays and vertebrae. Superficially, *B. podas*, *B. atlanticus*, and the others are precisely alike in the postlarval stages and pass through the same phases of development. Thus, omitting the characters mentioned, a description of the one applies exactly to the other. I have considered it unnecessary, therefore, to give a double series of figures, which would merely be duplicates of one another.

Description of the postlarval development in the Genus BOTHUS (*B. podas*, *B. atlanticus* etc.).

The postlarval history of *Bothus* falls naturally into two sharply divided sections or periods, distinguished by characters which might well be taken to belong to different genera. In the first period the postlarvae possess a long tentacle, pigment and an air-bladder, in the second period these characters suddenly and simultaneously disappear. In the great majority of preserved specimens there is not a trace of pigment in the second period[1], but the living specimens may have some red pigment, as mentioned above. At no time is there any trace of spine or spined plate in these species.

Fig. 12. *Bothus podas* (Delar.) 5 mm. × 12. St. 147, 25—VII—10.

The early postlarval stages from 5—12 mm. (Text-figs. 12—14) have the following characteristics. The body, to begin with, is very distinctly pear-shaped, even to the presence of a stalk. There is a long whip-like tentacle bearing a number of black spots of pigment. At the end of the notochord is a characteristic patch of pigment consisting of 4 to 5 large, feathered chromatophores grouped round the notochord at the very end, thus on the embryonic fin. The rest of the fish (in preserved specimens) is quite without pigment, excepting naturally the densely black eyes. These are small, whilst the head is large, that is, high. The mouth is small, but with heavy, well-developed jaws projecting slightly in front of the blunt, anterior profile. The liver is large, at first rectangular but soon tongue-shaped, the end of the tongue projecting in under the coil of the intestine to near the anus. Thus, as a rule, the coil of the intestine does not reach the ventral profile. This is also prevented by the characteristic, cartilaginous pubic bar, which extends even further back here than in *Arnoglossus*, namely to the rectum; the lower part of the latter thus comes to project slightly on the ventral aspect. In many preserved specimens, however, the coil of the intestine seems also to project slightly, lying to the one side of the pubic bar, but this is probably in all cases due to the preservation. There is a large, pigmentless air-bladder lying below the 6th to 8th abdominal vertebrae. At an early stage already the interspinous regions and dorsal and anal fin-rays are fully formed and the latter can be counted.

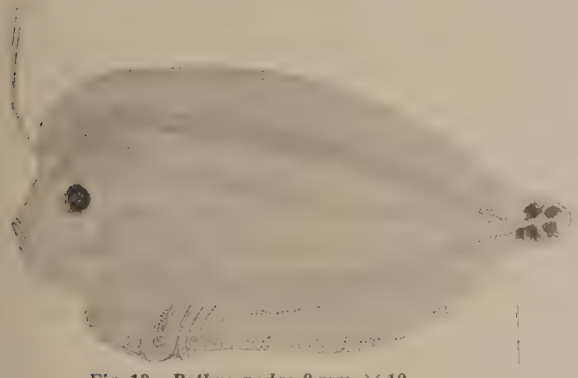


Fig. 13. *Bothus podas* 8 mm. × 10. St. 199, 25—VIII—10.

Fig. 14. *Bothus podas* (Delar.) 10 mm. × 10. St. 208, 29—VIII—10.

It is a remarkable feature in these species, that the end of the notochord does not bend upwards to the same extent as in *Arnoglossus* and other flat-fishes. In the latter the notochord has a double bend, first upwards and then again horizontally, the ural elements being formed under the first, sloping part and later pinching off the end part. In *Bothus* the

[1] Dr. SCHMIDT tells me, that the disappearance of the red pigment is certainly due to the formaline, as he has made experiments on the matter.

double bend is not distinct, the end of the notochord sloping almost evenly and slightly upwards from the end of the body, that is, end of the interspinous regions. The end of the notochord thus comes to project almost straight outwards and has the appearance of being the stalk of the pear-shaped body, as already mentioned. The ural elements are formed immediately posterior to the interspinous regions and, as usual, at some distance from the end of the notochord. With their growth and the growth of the caudal fin-rays the pigment on the embryonic fin gradually becomes reduced and pushed more and more upwards until it disappears with the enclosure of the notochord, when the caudal fin has asumed its final form at 12—13 mm.

Fig. 15. *Bothus podas* 13 mm. × 7. St. 21, 5—I—09.

At this period also the front part of the dorsal fin, which has gradually grown forwards and downwards in front of the eyes, comes to rest on the ethmoid region and the tentacle, which is very frequently cleft in preserved specimens, begins to disappear. The air-bladder shrinks to about one-third of its earlier size and has the appearance of a solid figure of 8, that is, bilobed with the one lobe smaller then the other.

The second period of postlarval development begins with the disappearance of the tentacle and pigment (text-fig. 15). We now have the well-known pellucid, "diaphanus", "Peloria" form so often referred to in the literature. The high, transparent form, the height being about 60 % of the length including caudal fin, thin almost as paper, with the blunt profile anteriorly, small jet-black eyes and small mouth is very distinctive of the species dealt with here and very probably of all species of *Bothus*[1].

Text-fig. 16, reproduced from a photograph, gives a very good impression of the form and characteristics of this second period in the postlarval development of these species. It is typical of the stages from 13 mm. to about 30 mm., except in one respect. Whilst the first period is marked by the gradual disappearance of tentacle, pigment and air-bladder, the second period is characterized by the growth of the ventral fins. These appear late; at 10 mm. they are merely small thickenings behind the base of the clavicles; at 13 mm. the rays are distinct, but the left ventral is not yet in advance of the base of the clavicles. Thus, in the first period these specimens might belong to *Arnoglossus* or half a dozen other genera and it is only the complete series, with transitional stages showing the disappearance of the organs mentioned, which has enabled them to be unmistakably identified. At 15 mm. the left ventral begins to show in front of the clavicles and thenceforward pushes gradually more and more anteriorly just as has been described in *Arnoglossus*. It does not become attached to the lower prong of the urohyal, which is also late in appearing, until about 28—30 mm. (*B. podas*), when metamorphosis may be said to begin. Long ere this, naturally, the asymmetry of the ventral fins is distinctly in evidence, the left in advance of the right, that is to say, the last 3 rays of the left ventral cover over the whole of the 6 rays of the right, which always lies behind the base of the clavicles, the first 3 rays being spread out forwards in front of the clavicles without

Fig. 16. *Bothus podas* 32 mm × 2.
St. 39, 1—II—09.
(From a photograph of a stained and mounted specimen).

[1] I have seen the late postlarval stages of in all 5 species of *Bothus*, including some from the Indian Ocean, and they all agree in the characters mentioned, the differences being shown in the form and in number of vertebrae and fin-rays.

any corresponding part of the right ventral. The structure of the pubic bones corresponding to this arrangement has already been described in an earlier paper (1900) and this structure alone is sufficient indication, that the "*Peloria*" of Cocco and Facciolà belongs first of all to the flat-fishes and within these to the subfamily *Bothinae*. The systematic importance of this character was not known to Cocco or Facciolà, who, in fact, considered, that their *Peloria* had only one ventral. There are two interesting points in connection with this faulty observation; firstly, neither author seems to have known, that Rafinesque had also failed to discover two ventral fins in his genus *Bothus* (and he was not the only one), so that, if this had been true, *Peloria* would have agreed very well with *Bothus*[1]; secondly, the number of rays in the supposed, single ventral of *Peloria* is stated by Cocco to be 5, but by Facciolà to be 13!

Metamorphosis takes place between 30 and 40 mm. in *B. podas*; of the other species, I have no specimens longer than 26 mm. and these are still mainly symmetrical, but from Steenstrup's description and also from an examination of his specimens, I judge that it metamorphoses at a somewhat smaller size, about 25—30 mm. This agrees also with what has been shown above in *Arnoglossus*, namely, that within the same genus the species with lower number of vertebrae and fin-rays metamorphoses as a rule at a smaller size.

My material of *B. podas* contains 22 specimens between 20 and 32 mm. in length, all symmetrical or at least as shown in the photograph text-fig. 16. There are 6 specimens from 31 to 36·5 mm., 5 taken pelagically and one on the beach in Sicily; further, from the Copenhagen Museum 3 specimens, 31·5, 33 and 35 mm. (spirit) from Sicily. Of the specimens over 30 mm. 3 had just completed metamorphosis and their lengths were 32, 36·5 and 31·5, the last being the Museum spirit specimen; the remaining 6 specimens had not yet metamorphosed. The size on metamorphosis is thus variable, as in other species, but may be taken to lie between 30 and 40 mm. On none of the metamorphosed specimens were the scales present at this length but a specimen of 46 mm. (spirit) has these and the pigment of the adult well-developed (see fig. 17 in text). Of the other species 4 specimens were found in the Copenhagen Museum, such as Steenstrup described them, beginning metamorphosis, metamorphosing and metamorphosed. They were all between 23 and 25 mm. in length, but naturally, as they have lain in spirit for many years, they are much shrunk. Allowing some 5 mm. for this, about 20 % of the total length, it seems, that this species metamorphoses below 30 mm.

The phenomena accompanying metamorphosis will be described in detail elsewhere and need only be briefly summarised here. Instead of the dorsal fin becoming detached in front to permit of the passage of the migrating eye, as in *Arnoglossus*, in *Bothus* it is firmly attached to the ethmoid and the eye finds its way through an opening in the tissues beneath the dorsal fin. The first anal interspinous bone bends forward ventrally to enclose the abdomen and the posterior prolongations of the cartilaginous pubic bars disappear, just as in *Arnoglossus*. Further, the ventral fin of the eye side, which already has a very elongated base, also grows backward just as in *Arnoglossus*, so that the membrane behind the last ray comes to lie close to the urinogenital opening and thus to cover over the ventral contour of the abdomen. The anus now opens on the blind side.

[1] Had Facciolà known the diagnosis of the genus *Bothus* by Rafinesque, he would hardly have written: "Diro soltante che la *Peloria Heckelii* non pue confondersi con nessun Pleuronettide conosciuto".

BOTHUS PODAS (Delaroche).

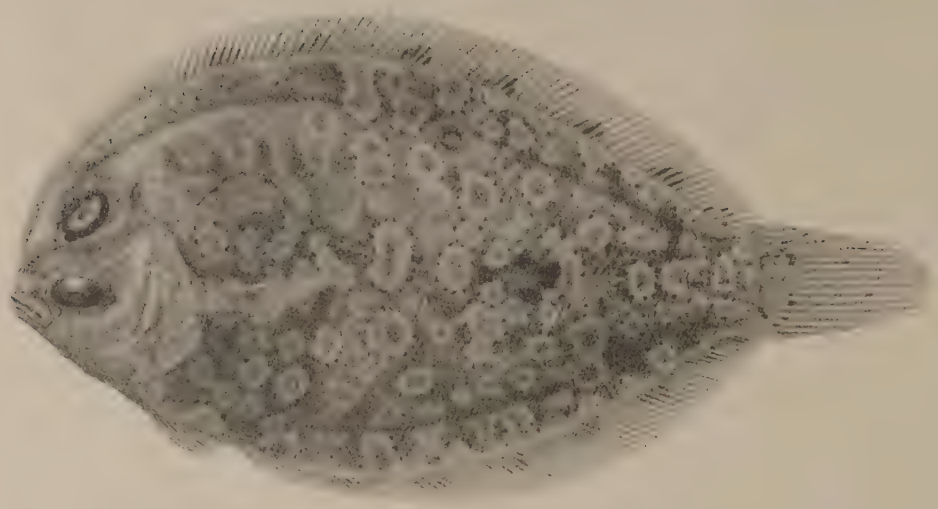


Fig. 17. Young specimen of *B. podas;* adult ♀ has similar characters. Drawing by N. Halkjær.

Fig. 17a. Head of adult ♂ *B. podas.*

Pleuronectes podas Delaroche 1809.
Bothus rumolo Rafinesque-Schmalz 1810.
Solea rhomboides Rafinesque-Schmalz 1810.
Rhombus mancus Risso 1826.
Rhombus (Bothus) rhomboides Bonaparte 1832.
Rhomboidichthys podas et *mancus* Günther 1862, Moreau 1881.
Bothus podas Steindachner 1868.
Platophrys podas Jordan and Goss 1889.

Postlarval stages:

Bothus diaphanus Rafinesque 1814.
Peloria Heckelii Cocco 1844, Facciolà 1885 (non *Rhomboidichthys mancus* Facciolà 1887).
Rhomboidichthys podas Emery 1883.

D. 85—(88—91)—94; A. 63—(65—68)—70; Vert. 10 + 28 (29) 30 = 38 (39) 40; P. 10—11/9—10; V. 6/6; C. 17; l. l. scales 18—20 + 62—66 = 82—84.

Adult characteristics: Habit rounded oval in female and young males, truncate anteriorly in the adult males, increasing with size or age, owing to protuberance caused by upper eye on top of head; scales very small, strongly adherent and ciliated on eyed side; smooth on blind side; by comparison with the total length (including tail) the greatest height is 46—47 %, caudal fin 19 %, head 21 %, left pectoral 14—16 %, right pectoral 11—12 %, left ventral 9—10 %. By comparison with the greatest height the distance of this from the base of caudal fin is 97—98 % (in *Arnoglossus* ca. 140 %). By comparison with the head the longitudinal diameter of the upper orbit is 38—39 %, left premaxilla 28—29 %, left mandible 43—44 %, interorbital space in females 21—29 % varying with age, 24—64 % in the males varying with age (see below). Lateral line forming a narrow arch over the pectoral on eyed side, defective on the blind side. Left ventral fin with a very extended base, the membrane from the last ray extending back to above the beginning of anal, thus covering ventral line of abdomen; right ventral small; pubic spines between ventrals hardly felt under the skin.

Colour: background greyish to dark brown, sometimes dull but usually shining, covered by greyish or bluish, opalescent spots each surrounded by a darker, brownish ring. These light spots are not regular but lobed at margins, with the lobes sometimes so deep as to appear petaloid; the brown ring round the spots is thus broken or discontinuous. There are two black or darker patches on the body, one just behind the arch of the lateral line, the other at posterior third of tail; the latter is most conspicuous and most constant, recalling that present at the same place in *Arnoglossus, Scophthalmus, Zeugopterus* and in fact most species of these subfamilies. There are also 7 black markings, not large, on the dorsal and anal fins opposite one another and in addition 2 or 3 on the front part of the dorsal. These, it will be remembered, are also characteristic of *Arnoglossus*. In young specimens, or when the fish is out of condition or has been rubbed, the motley colouring more or less disappears, and the whole body assumes an almost uniform, dun-brown colour (*Bothus rumolo* Raf.).

Size on metamorphosis: 30—40 mm.; size at first-maturity ca. 120 mm.; spawning-period April to September.

Sexual differences: There is no difference between the sexes in regard to length of any fin-rays, nor in colour. The differences are shown in the region of the head; the eyes being further apart in the males, especially in the adult condition. The concavity between the eyes is thus relatively shallower in the males. Further, mature adult males have a serrated ridge in front of the upper eye, formed by the margin of the bony orbit, also two small tubercles formed by the lachrymal bone and ectethmoid in front of the lower eye; neither of these characteristics is present in the female. Lastly, the maxillary prominence above the snout is more pronounced in the male when mature than in the females or immature males.

The following Table shows the changes, if any, in certain characteristics with size or age. As in the case of *Arnoglossus* the head is measured from the premaxilla to the first lateral line scale on the body, thus, to the margin of the posttemporal. The interorbital space is taken as the shortest distance between the orbits, care being taken to measure from the top of the ridge in each case. The absolute as well as the relative values are noted.

It will be seen, that the breadth ot the interorbital space, though variable, is certainly greater in the young males than in the young females. In 6 females below 100 mm. the interorbital space by comparison with the head varied between 19 and 22 %, in 9 males below the same length, however, between 25 and 32 %; in 3 females between 100 and 120 mm. it is 21—25 %, in 3 males of 100—105 mm. 24—29 %; in 11 females over 120 mm. it varies between 24 and 29 %. In the males there is no great increase in the relative size of the interorbital space until 140 mm. has been reached; between 120 and 140 mm. it remains about 30—40 %, between 140 and 150 mm. it is over 40 %, after 150 mm. there is a sudden spring to 57 % and then to over 60 %. It does not appear, however, that these great changes in the larger specimens have anything to do with the maturity of the sexual organs, as I find, that these are mature in the female at 115 to 120 mm., thus, presumably, about the same size or perhaps smaller in the male. This conclusion is also to some extent confirmed by the development of the tubercles. These are apparent about 120 mm., though they do not become prominent till much later. It is not quite clear, that the sexual differences in *Bothus* have any connection with the maturity of the sexual organs. The interorbital space is broader in young, immature males than in young, immature females, and the prominences on the head, if appearing about the time of first-maturity, are yet not characteristically developed until much later.

As the material is too small for a detailed analysis of the possible sexual differences in other characters with growth, I propose merely to give a brief summary of the variations.

Comparison of certain characters in the males and females of *Bothus podas* (Delar.)

No.	Total length mm.	Greatest height (without fins) mm.	Length of head mm.	Inter-orbital space mm.	Percentages: height/length	Percentages: head/length	Percentages: interor. sp./head	Serrated ridge at upper eye	Maxillary prominence	Tubercles in front of lower eye	Sex.
1	162	74	35	22	46	22	63	present	prominent	2 small	♂
2	161	73	34·5	22	45	21	64	do.	do.	1 small, 2 very small	
3	155	69	33	18	45	21	57	do.	do.	2 small	
4	152	66	33	18	44	22	57	do.	do.	1 small, 2 very small	—
5	150	66·5	31	17	44	21	45	not prominent	do.	2 small	—
6	147	66·5	32·5	18	45	22	55	do.	do.	do.	—
7	143	65	31	17	45	22	45	do.	do.	1 small	—
8	136	63·5	28·5	11	47	21	29	less prominent	do.	do.	—
9	130	59	27	8·5	46	21	31	do.	do.	do.	—
10	121	60	25	8	50	21	32	do.	do.	do.	—
11	105	49	21	5	47	20	24	not developed	not prominent	none	
12	102	47	21	5·5	46	21	26	do.	do.	do.	—
13	100	49	21	6	49	21	29	do.	do.	do.	—
14	99	47	21	6·5	47	21	31	do.	do.	do.	—
15	98	45·5	20	6·5	46	21	32	do.	do.	do.	—
16	97	44	20	5	45	21	25	do.	do.	do.	—
17	96	46	20·5	6	48	21	29	do.	do.	do.	—
18	96	44	21	5·5	46	22	26	do.	do.	do.	—
19	95	45	20·5	6	47	22	29	do.	do.	do.	—
20	91	42	19	5	46	21	27	do.	do.	do.	—
21	88	39	18	6	44	21	33	do.	do.	do.	—
22	81	35·5	17	4·5	44	21	27	do.	do.	do.	—
23	69	31	14	3	45	20	22	do.	do.	do.	♀
24	79	36	16	3·5	46	20	22	do.	do.	do.	—
25	85	41	17·5	3·8	48	21	22	do.	do.	do.	—
26	91	42·5	19	4	47	21	21	do.	do.	do.	—
27	93	42	19	4·2	45	21	22	do.	do.	do.	—
28	99	44	21	4	44	21	19	do.	do.	do.	—
29	108	52	23.5	5	48	22	21	do.	do	do.	
30	115	50	24	5·5	44	21	23	do.	do.	do.	—
31	117	52	24	6	45	21	25	do.	do.	do.	—
32	120	55	24	6·5	46	20	27	do.	do.	do.	—
33	121	58	25	6	48	21	24	do.	do.	do.	—
34	125	56	26	7·5	45	21	29	do.	do.	do.	—
35	127	55	27	7	44	21	26	do.	do.	do.	
36	128	59	27	6·5	46	21	24	do.	do.	do.	—
37	130	62	27·5	6	48	21	22	do.	do.	do.	—
38	131	58	27	6·5	44	21	24	do.	do.	do.	
39	132	63	26	7	48	20	27	do.	do.	do.	
40	134	60	27	6·5	45	20	24	do.	do.	do.	—
41	136	63	28·5	7	46	21	25	do.	do.	do.	—
42	136	66	29	8	49	21	28	do.	do.	do.	—

The variation in the number of fin-rays in the dorsal and anal fins and of the vertebrae can be seen from the following.

D.		85	86	87	88	89	90	91	92	93	94
♂	(21)		1	1	4	3	2	6	2	1	1
♀	(20)		1	4	4	2	4	3	2		
postlarval specimens	(41)	1	5	2	9	8	6	5	4		1
total	(82)	1	7	7	17	13	12	14	8	1	2

A.		63	64	65	66	67	68	69	70
♂	(22)		1	3	6	3	5	3	1
♀	(20)			3	6	3	6	1	1
postlarval specimens	(41)	1	2	6	5	11	11	4	1
total	(83)	1	3	12	17	17	22	8	3

C. Vert.	28	29	30
♂ (22)	5	15	2
♀ (20)	4	15	1
postlarval specimens . (65)	12	46	7
total ..... (107)	21	76	10

It will be noticed from these summaries, in the first place, that the postlarval specimens agree precisely with the later stages and secondly, that the majority of specimens show a comparatively limited range of variation in the number of fin-rays. For the dorsal fin about 70 % of the specimens are grouped about 88—91, thus a probable range of only 4 rays; this range is even more distinct in the case of the anal rays, where over 80 % are restricted to 65—68 rays. The possible range is apparently 10 rays for the dorsal fin and 8—9 rays for the anal. The number of caudal vertebrae is mostly 29, with a slight skewness towards 28. The number of abdominal vertebrae was found to be invariably 10, wherever counted.

The variation in other dimensions can be seen from the following summaries.

Greatest height relative to total length

	44	45	46	47	48	49	50
42 spec.	8	10	10	5	6	2	1

aver. 46·0 %.

Distance of greatest height to tail relative to G. H.

	91	92	93	94	95	96	97	98	99	100	101	102	103
41 spec.	1	1	1	2	4	8	3	2	4	7	4	2	2

aver. 97·8 %.

Length of head relative to total length

	20	21	22
♂ (22)	1	15	6
♀ (20)	5	14	1
total (42)	6	29	7

aver. 21 %.

Length of mandible relative to length of head

	39	40	41	42	43	44	45	46	47
♂ (21)	1	2	1	6	6	1	2	1	1
♀ (19)			1	3	3	4	4	3	1
total (40)	1	2	2	9	9	5	6	4	2

aver. 43·3 %.

Longitudinal diameter of upper orbit relative to head

	34	35	36	37	38	39	40	41	42	43	44
♂ (19)	1	1	3	5	3	4	1	1			
♀ (19)			2	1	4	2	4	3	1	1	1
total (38)	1	1	5	6	7	6	5	4	1	1	1

aver. 38·5 %.

Length of premaxilla relative to length of head

	24	25	26	27	28	29	30	31	32
♂ (20)	1	1	2	3	5	7			1
♀ (19)	1		2	3	4	7	1		1
total (39)	2	1	4	6	9	14	1		1

aver. 27·9 %.

The greatest height of the body (without fins) is not far from 50 % of the total length with caudal fin. The form of the fish is thus as a rule very high or broad, especially if we take the dorsal and anal fins into consideration. If we exclude the caudal fin, the form is very nearly that of an ellipse with the major axis twice as great as the minor axis. In the more oval form of *Arnoglossus* the major axis was $2^1/_2$ times as great as the minor axis.

In the case of the head a distinction is drawn between the males and females. The slightly larger head in the males, shown by the data, can hardly be depended on, as the numbers are so small, though it would seem quite natural, that the males have the longer head owing to the position of the upper orbit in the adults. What is more noteworthy however, is that the females have a larger mouth and upper orbit. If the head is longer in the males, these other characters should appear relatively smaller in the percentages, if of the same size. Thus, the relative difference shown would be greater absolutely. A larger material would be required, however, to confirm these indications, as it is quite possible, that there is no difference between the sexes here. A further noteworthy point is the very slight variation in the length of the head.

I have examined the scales in half a dozen specimens, to determine the age. As in *Arnoglossus* the estimate of the age depends in great part on the first apparent ring — this may mark, namely, the end of the second year and in any case is not clear. According to a provisional examination, the rate of growth is very similar to that in *A. laterna*. At the end of the first year a length of 60 mm. may be reached, whilst specimens of 120—130 mm. are at least 3 years old. Whether *B. podas* is mature at the beginning of its apparent 2nd or 3rd year, I have been unable to determine.

The spawning period lies mostly in early summer but there seems to be some scattered spawning throughout the year. If we estimate that 13 mm. is reached on an average about 3 months after spawning, the period of spawning can be seen roughly from the following data.

	Jan.	Febr.	April	July	August	Sept.	Dec.
Number below 13 mm.	0	0	1	7	76	4	5
— above 13 mm.	5	6	22	11	2	1	29

According to these figures the main spawning-period would lie in April to June, but the presence of 5 small specimens between 10 and 13 mm. in December and also of older specimens in January, February and April would indicate, that some spawning occurs as late as September as also that the pelagic existence must be very prolonged. The largest specimens taken pelagically were 32 mm. long, and these were taken in the winter out over great depths (1000—2000 m.).

Distribution. The distribution of *Bothus podas*, as shown by the postlarval specimens, is noted on Chart 6, p. 110 along with that of the Atlantic species; the records derived from the trading-vessels, both in the Mediterranean and Atlantic, as well as those of the "Thor" are included. It will be seen, that *Bothus podas* occurs everywhere in the Mediterranean, even in Levantine waters from which the *Arnoglossus* species were wanting. In the Atlantic it occurs at the Azores and some postlarval specimens were taken to the west of those islands. Towards the north it has not been taken north of 40° N. L.; its southern boundary is unknown, but if GÜNTHER's specimen (1889) belonged to this species, as seems probable, it occurs off Sierra Leone and postlarval specimens have been taken by Danish trading vessels south of the Cape Verde Islands (12°20′ N., 24°04′ W.; see Chart).

Seeing that the postlarval stages of this species belong preeminently to the surface layers, only 8 specimens in all were taken with more than 100 meters wire out and these probably on hauling in, it is

certain that very large quantities are carried into the Mediterranean from the Atlantic. The following table shows the depths over which the postlarval specimens were taken in the Mediterranean and Atlantic.

Depth	0—100	100—500	500—1000	1000—2000	> 2000 meters
No. of specimens	3	7	9	72	76

BOTHUS ATLANTICUS.

?*Pleuronectes argus* Bloch 1783.
?(*Rhombus ocellatus* Agassiz 1829).
?*Platophrys ocellatus* Jordan and Goss 1889.

Postlarval stages:
"*Plagusiæ*" Steenstrup 1864 and 1878.

In their useful work on the Pleuronectidae of America and Europe, Jordan and Goss fully recognise the difficulties attending the proper discrimination of the species of the genus *Bothus*. "The following analysis of the species of *Platophrys* will doubtless be found to be very unsatisfactory. There are certainly three species (*podas, maculifer* and *lunatus*), which are known to be distinct in their adult state". They then proceed to give a diagnosis of 8 different species. The procedure does not seem quite consistent with the statement quoted, and perhaps the meaning is only, that we should not attach too much importance to either. Both cannot be accurate or correct, and the evidence suggests, that both are wrong.

For example, the species *spinosus*, which they regard as extremely doubtful, is given the fin-ray formula: D. about 74, A. about 57, yet the authors state, that "in all respects, unless it be the color, it agrees with the European "*Pl. podas*", which as shown above has a much higher fin-ray formula. Again, they place Bloch's *B. argus* under *B. lunatus*, though Bloch gives D. 79, A. 69 for his species, whilst *B. lunatus* has D. 95—96, A. 70—76. It is evident, therefore, that Jordan and Goss have not attached much weight to the number of fin-rays. But we can take it as certain, that in *Bothus* as in *Arnoglossus* the principal specific character is just the fin-ray formula (combined with the number of caudal vertebrae).

Further, it has been shown under *Arnoglossus*, that there is a certain amount of correlation between number of vertebrae and number of fin-rays. Thus,

23	caudal	vertebrae	are	associated	with	.....	D. 75— 78, A. 52—56
28—29	—	—	-	—	—	.....	D. 86— 90, A. 64—68
30—31	—	—	-	—	—	.....	D. 91— 94, A. 70—73
33	—	—	-	—	—	.....	D. 98—100, A. 76—79
34	—	—	-	—	—	.....	D. 112—114, A. 87—90

Whilst we cannot assume beforehand, that the same law of correlation will hold good in *Bothus*, both the presumption and evidence would indicate, that it does so. In the first place, the structure is very similar in both genera, the D. and A. fins going right to the base of the caudal fin. Secondly, in the two species of *Bothus* for which we have a large material, we find

26	caudal	vertebrae	associated	with	..... D. 81—84, A. 60—63
29	—	—	—	—	..... D. 88—91, A. 65—68

It would appear, therefore, that the same law of correlation holds good for both genera, and in any case we can use it provisionally to ascertain the probable number of (known) species of Bothus

occurring on the Atlantic coasts of America. Here we can only make use of the fin-ray formula. From JORDAN and Goss we have:

B. spinosus	D. ca. 74, A. ca. 57
B. ocellatus	D. 85—90, A. 64—67
B. maculifer	D. 90—95, A. 70
B. lunatus	D. 95, A. 70
B. ellipticus	D. 105, A. 80

The Copenhagen Museum contains a number of specimens of *B. ocellatus* and *lunatus*, and I may state here the number of fin-rays I have found in them. In *B. ocellatus* (2 specimens) D. 82—84, A. 64; in *B. lunatus* (5 specimens) D. 94—96, A. 71—75.

There would thus be at least 4 species here, namely, *B. spinosus*, *B. ocellatus*, *B. lunatus* and *B. ellipticus*. JORDAN and Goss state expressly, however, that *B. maculifer* is distinct from *B. lunatus* in the adult state, and the differences in the size of head and mouth are certainly significant; *B. maculifer* coming nearer to *B. ocellatus* in these characters. I have not seen any specimens of *B. maculifer*.

In addition to the above, I have found a small specimen in the Copenhagen Museum, which does not fit into the above scheme. It is from the Danish West Indies (St Croix) and has D. 80, A. 58. Although only about 70 mm. long, the eyes are wide apart and it thus has the appearance of the adult male *Bothus*. *B. ocellatus* does not assume this appearance until it is over 100 mm., and *B. lunatus* not until about 200 mm. This small specimen may belong to JORDAN and Goss' "extremely doubtful" species *B. spinosus*, but the incomplete description given of the latter does not permit of identification.

Reviewing the above, it may be concluded, that there are at least 5 and probably 6 distinct species of *Bothus* on the Atlantic coasts of America. The question is now, to which of these species can we refer the postlarval specimens, which have been taken in large numbers over wide areas of the North Atlantic? For the sake of immediate comparison, I give here the number of fin-rays found in 74 specimens (oceanic form, Sts. 251, 329, 439 and 445):

D.	77	78	79	80	81	82	83	84	85	86	87	88	89
	1	1	2	4	13	13	16	12	4	4	2	1	1

A.	58	59	60	61	62	63	64	65	66
	3	9	14	14	14	10	6	3	1

It will be seen at once, that the fin-ray formula of these specimens does not agree with any of the species of JORDAN and Goss. The nearest species is *B. ocellatus*, but if the fin-ray formula given by the American authors for that species is representative, these are two different species. The great majority of the specimens (probable range D. 81—84; A. 60—63) fall below the fin-ray formula for *B. ocellatus* given by JORDAN and Goss (D. 85—90; A. 64—67).

Owing to this difference and owing to the admittedly unsatisfactory diagnoses of the American species given by JORDAN and Goss, I have felt obliged either to revive BLOCH's *B. argus* or to coin a new name for these specimens. BLOCH gave D. 79, A. 69 as the fin-ray formula of his "*Pleuronectes argus*". It is clear from the above correlation between the number of rays in the dorsal and anal fins, that there is some mistake in this formula, either in counting or in printing. D. should be 89 or A. should be 59 to make BLOCH's species fit in with the fin-ray formulae of *Bothus*. In referring it to *B. lunatus*, JORDAN and Goss have assumed the former — though, even then, it does not agree with *lunatus* —. Further, JORDAN and Goss evidently relied also on the blue spots on the fins and head in BLOCH's figure, which they consider diagnostic of *B. lunatus*, but in some of the specimens in the Copenhagen Museum the spots have lost the blue colour and, as shown under *B. podas*, we have to be very careful in ascribing specific importance to the colour scheme in *Bothus*. Owing to these doubts, I think it best to give the new name *atlanticus* to these postlarval specimens. The small adult specimen of the Copenhagen Museum, which came from the West Indies, may belong also to this species.

Collections of postlarval BOTHUS taken in the surface waters of the Atlantic by Danish vessels during the years 1911—12.

Diameter of net opening 1—2 m.; duration of hauls ca. 30 minutes. (a) means 2 hauls.
Except where otherwise stated, the data refer to *Bothus atlanticus*.

Station, month & year	Position		Approx. depth at station meters	No. of specimens	No. of caudal vertebrae		Remarks
	North	West			mode	range	
1911							
March							
250	20°38′	64°35′	5300	(a) 13	26	25-26	Stations east of the Azores (264-269) and north of 38° N. L. gave no *Bothus*.
251	22°16′	63°05′	5850	5	26	25-26	
252	23°53′	61°36′	6300	(a) 3	26	26	
253	25°38′	59°52′	6100	(a) 4	26	26	
254	26°45′	59°35′	7000	1	26		
255	27°42′	58°00′	6300	2	..	25-26	
257	30°05′	52°58′	5120	2	26		
258	32°54′	46°44′	5300	6	27	26-27	
261	35°27′	37°18′	3500	1	27		
262	36°13′	33°50′	2930	1	29	..	near Azores (*B. podas*).
Febr.							
272	30°30′	49°57′	5120	19	26	25-27	
March							
273	15°10′	61°24′	1900	2	26		
June							
293	26°35′	53°59′	..	4	..	26-27	
294	34°59′	42°50′	..	2	26		
299	37°05′	54°34′	5300	6	26	26-28	
300	37°10′	54°40′	5300	2	27	..	*Bothus* sp. 3.
303	39°31′	49°39′	7300	13	26	26-27	
May							
315	39°50′	49°30	5490	1	27		
June							
328	27°53′	47°40′	3660	1	27		
July							
329	25°32′	52°08′	5660	7	26	26-27	
330	32°03′	39°00′	3110	2	26		
334	38°10′	40°50′	4570	6	26	26-27	
Septbr.							
345	35°15′	44°09′	4940	1	26		
354	42°45′	64°30′	..	1	27	..	
Octbr.							
355	38°45′	69°56′	..	39	27	26-28	*Bothus* sp. 3.
356	42°11′	60°10′	..	8	27	26-27	
Novbr.							
394	16°50′	61°50′	..	2	27	..	
413	38°06′	25°37′	..	(a) 3	29	29-30	near Azores (*B. podas*).
434	19°36′	47°13′	3200	1	26		
435	19°26′	50°12′	5200	3	26	26-27	
436	19°20′	51°57′	..	1	26		
437	19°11′	54°15′	..	1	26		
438	19°09′	55°48′	..	(a) 49	26	25-27	
439	18°58′	59°36′	6000	(a) 101	26	25-27	
440	18°45′	62°20′	..	(a) 11	27	26-27	*Bothus* sp. 3.
Decbr.							
468	34°50′	15°54′	..	2	29, 30	..	*B. podas*.
469	33°20′	16°58′	..	1	30	..	
470	0°38′S	33°31′	3400	16	27	26-28	*Bothus* sp. 3.
1912							
Febr.							
441	18°55′	64°27′	..	10	26	25-27	
442	20°16′	62°48′	5200	(a) 44	26	25-28	
443	23°15′	58°43′	..	(a) 7	26	25-26	
445	28°42′	48°45′	..	2	27		
446	30°10′	45°41′	4200	(a) 4	26	25-27	
452	27°20′	46°00′	..	1	26		
464	30°31′	50°35′	5000	1	26		
April							
471	20°44′S	39°53′	3000	26	27	26-28	*Bothus* sp. 3.
521	34°45′	15°42′	..	1	30	..	*B. podas*.
May							
481	42°12′	62°15′	..	2	28		
491	23°45′	59°22′	5200	1	26		
493	39°38′	37°37′	..	1	26		
494	21°18′	59°38′	5600	(a) 6	26		
June							
487	38°25′	47°52′	..	3	26		
495	32°05	37°40′	3600	(a) 3	26	26-27	
July							
525	12°20′	24°04′	5100	2	29	..	*B. podas*.
561	0°39′S	31°23′	3400	(a) 26	27	26-28	*Bothus* sp. 3.
Septbr.							
554	31°30′	43°00′	..	1	26		
557	30°25′	50°50′	..	2	26		
563	4°57′S	32°41′	4000	4	27	26-27	*Bothus* sp. 3.
661	33°53′	15°50′	..	1	30	..	*B. podas*.
Octbr.							
630	36°45′	30°10′	3600	5	29	..	*B. podas*.
646	32°10′	17°22′	..	9	29	29-30	
651	19°35′	39°20′	..	19	26	25-27	
664	4°09′	27°31′	..	2	..	27-28	*Bothus* sp. 3.
Novbr.							
653	19°03′	52°38′	..	1	26		
654	18°56′	59°56′	..	(a) 12	26	25-27	
Decbr.							
666	10°08′S	35°02′	..	2	26	..	*Bothus* sp. 3.
667	0°50′S	30°39′	..	35	27	26-28	
668	10°42′	25°28′	..	2	29	..	*B. podas*.
677	26°10′	19°00′	..	5	26	25-26	
678	26°08′	57°20′	..	15	26	25-27	
679	26°10′	65°08′	..	17	26	25-27	
680	26°09′	72°47′	..	322	26	25-27	
1913							
Jan.							
685	36°30′	46°40′	..	4	26	26-27	
Febr.							
688	39°23′	38°21′	..	1	26		
693	0°00′	30°00′	..	6	27	27-28	*Bothus* sp. 3.
694	10°00′	27°00′	..	1	28	..	?

A list of the postlarval *Bothus* which have been collected by Danish vessels in the surface-waters of the North Atlantic during the last two years is given in the accompanying Table. It will be seen, that the stations extend right over the Atlantic, from Europe and Africa to America and from about 20° S. lat. to about 40° N. lat. The approximate depths at the places are given in some cases. The total number of *Bothus* taken amount to nearly 1000 and it may be mentioned that the majority of the hauls

taken within the area mentioned contained some *Bothus* postlarvae. Each haul was only of about half an hour's duration, and the impression given is, that there must be enormous quantities of these postlarvae over all parts of this zone.

On examining the column showing the mode of the caudal vertebrae, that is, the number which occurs most frequently, it will be seen, that there are at least 2 distinct series, i. e. species, the one with 26 or 27, the other with 29 or 30. The latter only occurs from about the Azores eastwards, the other from slightly west of the Azores westwards. The former can at once be identified with the Mediterranean species *B. podas*, the other is the series which I refer to *B. atlanticus*. From the specimens which I have examined in Copenhagen, it is clearly the same species as that on which STEENSTRUP based his famous description of the migration of the eye in flat-fishes, nearly 50 years ago. His specimens were also collected in the North Atlantic in the same manner, by vessels trading between the West Indies and Europe.

The question whether the specimens taken in the Western Atlantic belong all to one and the same species or to 2 or more, can be approached from two sides; either by analysing the data as a whole or by comparing the separate hauls one with another. The latter method is the simpler and probably the more accurate for most of the samples. As shown in the Table, the only character which has been determined in the majority of the specimens is the number of caudal vertebrae. This character is naturally more precise than the number of fin-rays and is thus better suited for the distinction of the species; apart from these two characters, these postlarval specimens are indistinguishable from the postlarval series of *B. podas* taken in the Mediterranean.

On comparing the samples one with another, we may consider, to begin with, those which contain more than 10 specimens. These are shown in the following Table; the numbers in brackets indicate the total number in the sample.

Station	No. of specimens	caudal vertebrae			
		25	26	27	28
250	13	4	9		
272	19	2	11	6	
303	13		11	2	
355	(36) 20		5	11	4
438	49	15	33	1	
439	105	25	67	13	
440	11		5	6	
441	10	3	5	2	
442	(44) 41	3	20	17	1
470	16		1	11	4
471	(26) 24		4	13	7
561	26		2	22	2
651	16	3	13	3	
654	12	2	9	1	
667	35		1	27	7

With some 4 to 5 obvious exceptions, these samples are consistent with the view, that we are dealing with a single species in which the number of caudal vertebrae centre round 26 as the mode or greatest frequency with 25 and 26 almost equally common but greatly in the minority by comparison with 26. For the purpose of determining this more precisely, we may combine the samples 434—439, which were taken in the same month and along the same tract of water. We then have

25	26	27	
40	105	15	160 specimens (aver. 25·85)

The form of the curve here is precisely the same as that found for the caudal vertebrae of *B. podas* (p. 103; 28—29—30: 21—76—10) and this is very good evidence, that we are dealing here with homogenous material. The variation is slight; the standard deviation is $\pm \cdot 36$ and the probable error of the average only $\pm \cdot 19$, so that if we could take these samples (434—439) as representative, there is practically no probability of any frequency occurring beyond 27. Similarly, there is practically no probability of the mode moving from 26 to 25 or 27 in any other group of samples containing a fairly large number of specimens. Again, if we have a large number of small samples, each containing only a few specimens, 25, 26 or 27 may occur alone or 26 may occur alone with 25 or 27, but on the whole 26 should be twice as frequent as the other two combined. Grouping these small samples with less than

10 specimens together and omitting those to be mentioned below, we have (stations 251—261, 293—294, 328, 329, 330, 334, 345, 443—464, 487, 491—495, 554, 557, 653).

25	26	27
5	57	14

Thus, where the specimens are taken singly or only a few at a time, 27 is more frequent than 25, but the type is preserved, for the mode has the same relative frequency as before. Again, we may take the samples which have more than 10 specimens, which conform to the type but which have not been included above (250, 272, 651, 654):

25	26	27
11	42	10

It is evident, that these three groups represent different selections of the frequencies belonging to one and the same species. Combining them all together, therefore, we should have a good representation of the variability of the species.

25	26	27	
56	204	39	299 specimens

Testing the remainder of the samples by means of this type, we see that there are some deviations, for example, 355, 442, 470, 471 and possibly others. Now, 355 is one of a group of 3 samples taken near the coast of the United States (see Chart) and 470 etc. were taken near to or south of the equator; for these we have

	26	27	28	
Stations 354, 355, 356	7	18	4	
Stations 470, 471, 561, 563, 664, 666, 667	11	77	21	
	18	95	25	138 specimens

This is quite a different picture from the above and clearly suggests, that we are dealing with a different species (*B. ocellatus*?). By comparison with the first species and with the results quoted above for *B. podas*, these two groups might be said to constitute a representative sample of this other species, for the relative frequencies about 27 as mode are almost precisely the same as in the other two cases with modes 26 and 29.

Again, 442 may be grouped with the adjacent stations 440, 441, 394 and 273, which give:

25	26	27	28
7	31	26	1

This is also a somewhat different picture from the main species and is more divergent than we should expect if dealing with the one species. We may even detect another, fourth group in the samples 299, 300, 303 and 315, consisting, however, of only a small number of specimens:

26	27	28
15	6	1

Whilst the second group referred to (354, 355, 356, 470, 471, 561, 563 etc) seems undoubtedly to represent a distinct and different species, these last two groups rather indicate a mixing of the main group with another, perhaps the same species in all cases. The explanation would seem to be, therefore, that the main group (*B. atlanticus* with 26 as mode) is mainly oceanic, living remote from the coasts on the whole. The second group, representing a different species (*B. ocellatus*? with 27 as mode), lives to the south of the equator and its postlarvae are inhabitants of the South Equatorial Current, which washes the northern coasts of South America and the West Indian Islands and then flows northwards as the Gulf Stream towards the Newfoundland Bank. The border regions of the two species would thus be, firstly,

Chart 6. Distribution of various species of *Bothus* in the Atlantic and Mediterranean.

● = *B. podas* (29 caudal vertebrae on an average).
○ = *B. atlanticus* (26 – — - - —).
× = *Bothus* sp. 3 (27 – — - - —).

Bothus sp. 3 possibly contains 2 species with the same number of caudal vertebrae, but it may be everywhere the one species (*B. ocellatus*?).

about 10° N.L., then the West Indian Islands (samples 440, 442) and lastly, along the outer edge of the Gulf Stream (samples 299, 303), whence we have these divergent, seemingly mixed samples. Consideration of the distribution in more detail will perhaps throw further light on these points.

Distribution. The data of the collections in the North Atlantic have been noted down on the accompanying Chart and the Mediterranean records of *B. podas* have also been included for the sake of comparison. *B. podas* (with 29 caudal vertebrae on an average) is represented by the black spots, *B. atlanticus* (with 26 caudal vertebrae on an average) by circles and the other species (*B. ocellatus*?) with 27 caudal vertebrae on an average) by crosses.

It will be seen, that the areas of distribution of *B. podas* and *B. atlanticus* almost meet south-west of the Azores. One specimen of *B. podas* was taken at St. 262 (33° 50' W.), whilst a specimen of *B. atlanticus* was taken by the same vessel (Ingolf) on the same cruise at St. 261 (37° 18' W.) — or a distance of about 150 miles only from the other. No specimens of *B. podas* have been taken further to the west and none of *B. atlanticus* further to the east. As mentioned in discussing the distribution of *B. podas*, 34° W. may be taken as the westernmost limit of this species in these latitudes and no specimen has as yet been taken north of 40° N. in the Atlantic.

With regard to *B. atlanticus*, the eastern limit may be placed at 37° W. The single specimen taken at St. 261 is not an isolated occurrence east of 40° W., for 21 specimens were also taken at 39° W. (St. 330, 651). Further, 6 specimens were taken at 40° 50' W. Including the latter sample 46 specimens have been taken in 13 hauls between 40° and 50° W. (excluding the samples 303 and 315). Between 50° and 55° W. 21 specimens have been taken in 9 hauls (excluding samples 299 and 300), between 55° and 60° W. 183 in 15 hauls and west of 60° W. 21 in 5 hauls (250, 251 and 252).

If we exclude the samples 354, 355 and 356, which may belong to a different species, the furthest north records of *B. atlanticus* lie about 40° N. The highest stations (299, 300, 303 and 315) are within the influence of the Gulf Stream and, as already indicated, the specimens taken there can only in part be ascribed to *B. atlanticus*. Nevertheless, the northern limit may be placed at 40° N.; between 30° and 35° N. 39 specimens were taken in 10 hauls, one haul alone (272) yielding 19. Between 25° and 30° N. 22 specimens were taken in 9 hauls, between 20° and 25° N. 72 in 9 hauls. South of 20° N. 12 hauls (excluding the stations near the West Indian Islands) yielded 188 (4 hauls yelding 150).

In general, therefore, the average catch per haul seems to increase from east to west and from north to south, though it has to be remembered, that comparisons are hardly possible with such material, collected by different vessels under diverse conditions. For example, there is a curious break or depression in the east-west and also the north-south series, between 25°—30° N. and 50°—55° W., but this is accidental, for in the meeting square of these two zones we have 2 stations (293 and 329) which have a good average number of specimens (over 5). Again, the statement, that the numbers increase from east to west and from north to south, though it is probably quite in accordance with the reality, depends on the large numbers taken at the two stations 438 and 439. But it is certain, that the southern limit lies further south than 20° N.

To a certain extent, the samples seem to indicate, that the species spreads out fan-wise from the West Indian Islands towards the north and east, decreasing in numbers with the distance. Let us assume, therefore, for the moment, that the adults are distributed along the American Continent, from Brazil over the West Indies to the United States (*B. ocellatus* is said to have this distribution). The direction of the currents (North Equatorial Current, Gulf Stream) would then tend to bring the pelagic larvae round towards the Azores. This explanation seems the most natural and simplest at first sight, for the flat-fishes are not supposed or known to live at depths greater than 1400—1500 meters, whereas we find these postlarvae here in quantities over 4 to 5 times that depth and remote from the coasts. The question is, whether this hypothesis will really explain the facts.

The first difficulty that occurs to one, is whether the larval and postlarval life is so prolonged, that these specimens may be carried by the currents over the immense distances in question here (1 to 2000 miles). Under *Arnoglossus Rüppeli* and again under *B. podas*, it has been suggested, that the postlarval life may extend over a whole year. Let us assume this as the extreme limit. Now the distance from the West Indian Islands to Stations 261, 330 and 334 is about 2000 miles. If the drift is in a straight line and is continued evenly and steadily throughout the whole year, this would mean a drift of about 6 miles per diem. This is the least rate of drift; but the specimens taken at Stations 261 and 330 were all 13 mm. in length and the 6 specimens taken at St. 334 were only 8·5 to 12 mm. in length. Further, a glance at the Table below p. 113, which gives a summary of the lengths in the different months (excluding the West Indian specimens and the specimens taken near the American coast), will show, that the smaller sizes below 14 mm. are more abundant than the larger. For the sake of comparison, I may give the sizes of the specimens taken in the samples near the West Indies (Stations 273, 394, 440, 441 and 442).

< 10	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 mm.
7	7	6	11	11	6	2	10	1	3	1	1	1			2

The picture is, in fact, essentially the same, whether we take the samples near the Islands or out in mid-ocean. The smallest sizes occurred both at the greatest distances from as well as near land. Thus, we may conclude, that all stages occur out in mid-ocean. To explain their presence there, we must assume, either that the embryonic development is exceedingly prolonged (which is exceedingly improbable) and this with the early larval life occupy a full year or more, or that the rate of drift is many times 6 miles per diem. Neither of these conclusions is acceptable and in any case, is there any drift towards the centre of the region under consideration?

The centre of the region lies in the Sargasso Sea, which is practically dead water with the currents moving in an anticyclonic direction round about. Thus the stations 250, 251, 252, 253, 254, 255, 293, 329, 443, 445, 446, 464, 554, 567 and 452 are all within the Sargasso Sea; the Stations 299, 300, 303, 315, 487 and perhaps 334 are near the northern margin and probably somewhat under the influence of the Gulf Stream which flows here from west to east; stations 434, 435, 436, 437, 438, 439, 651, 653 and 654, again, are just to the south of the Sargasso Sea and perhaps under the influence of the North Equatorial Current, which flows from east to west — i. e. towards the West Indian Islands. It is thus impossible to explain the distribution of these postlarval specimens over the ocean as due to currents carrying them from the American Continent or Islands.

These two factors, the presence of all developmental stages in mid-ocean and the absence of currents or presence of contrary currents, quite dispose of the seemingly natural hypothesis, that these postlarval specimens owe their existence to adult fishes living near the coasts. These postlarval specimens in mid-ocean — 1000 miles from anywhere — have been derived from adults living near or at the spot where they were found. The only question is now, whether these adults live pelagically or at the bottom (3000 to 7000 m.). I vote for the former and imagine, that the Sargasso Sea has a pelagic, flat-fish fauna of its own.

Consideration of the distribution thus leads to the same conclusions as the analysis of the number of vertebrae. Excluding the eastern *A. podas*, our material really contains 2 species, the one oceanic (*B. atlanticus*) belonging to the Sargasso Sea and mid-Atlantic waters further south and only approaching land at the West Indian Islands, where its postlarvae (and probably adults) mix with those of a second species (*B. ocellatus?*), which belongs to the American mainland, but whose postlarvae may also occur far out to sea in the Gulf Stream.

The extension of *B. atlanticus* to the south can only be given approximately. The specimens from below the equator (Sts. 470, 471, 561, 563, 666, 667) belong to the 3rd species. Thus, the boundary

lies between 0 and 20° N. L., probably nearer the latter. Regarding the limits of the 3rd species we really know nothing at present. JORDAN and GOSS state, that *B. ocellatus* occurs from Rio Janeiro in the south to Long Island in the north and Dr. L. L. MOWBRAY, director of the Boston Aquarium, formerly resident on the Bermudas, kindly informs me, that it is the common species in Bermuda waters. Consideration of the direction of the currents will show, how this species may bound *B. atlanticus* on the south and west, whilst *B. podas* bounds it to the east.

Spawning period. It is of interest to inquire, whether this oceanic, seemingly pelagic species of flat-fish has any definite spawning period. Presumably, the conditions under which it lives are exceedingly uniform, by comparison, that is, with the extremes our more northern fishes are acquainted with. The latter we know to have more or less definite spawning times, that is, certain times of the year when the temperature and possibly salinity suit them best for that purpose. What should we expect, where there is but little variation in temperature and salinity throughout the year?

In the following Table I have arranged the available data of the samples according to the months in which they were taken in the years 1911—12. Only the oceanic species *B. atlanticus* is taken into consideration and the range of size of the specimens taken.

Size in mm.	Febr.		March		May		June		July		Sept.		Oct.		Novem.	
	'11	12	'11	'12	'11	'12	'11	'12	'11	'12	'11	'12	'11	'12	'11	'12
< 10	..	..	..	..	..	..	2	..	1	..	..	..	..	..	2	2
10	..	..	1	..	..	..	5	..	3	..	..	.	..	..	10	5
11	2	1	2	..	..	..	6	..	1	..	..	1	..	..	11	2
12	11	7	7	..	..	1	8	4	1	..	1	1	..	1	23	1
13	2	2	10	..	..	..	2	2	2	..	..	1	..	10	18	2
14	..	..	6	..	..	1	1	..	..	..	..	..	..	8	18	
15	..	1	3	..	..	1	..	..	1	..	..	..	..	..	15	
16	2	..	6	..	1	1	1	..	3	..	..	..	..	..	16	
17	..	1	1	..	..	..	..	..	..	..	..	..	..	..	8	
18	..	..	1	..	..	..	..	..	1	..	..	..	..	..	8	
19	..	1	..	..	..	2	..	..	1	..	..	..	..	..	9	1
20	1	1	1	..	..	..	..	..	1	..	..	..	..	..	5	
21	1	..	1	..	..	..	1	..	..	..	..	..	..	..	8	
22	..	..	..	..	..	1	..	..	..	..	..	..	..	..	8	
23	..	1	..	..	..	..	1	..	..	..	..	..	..	..	6	
24	..	..	..	..	..	1	..	..	..	..	..	..	..	..	4	
25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	
26	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	
27	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	
Total	19	15	39	..	1	8	28	6	15	..	1	3	..	19	173	13
No. of hauls	1	7	14	..	1	4	6	3	3	..	1	2	..	1	11	3

It is evident, that the small specimens occur throughout the whole year and it is hardly possible to talk of any restricted spawning-period. If we were to suppose a spawning-period, for example, in the spring, lasting on to the autumn, this would account for the occurrence of the small specimens in June, July and November, but we should then have to believe, that the small specimens persist throughout the winter without growing, i. e. for six months or so, to account for their presence in February and March. The more reasonable conclusion seems to be, that *B. atlanticus* may spawn throughout the whole year, with a maximum probably in early summer to autumn.

Since the above was written, a new series of collections has been made across the Atlantic in December 1912 at the 26° of North latitude. Altogether there are 4 samples in the series containing postlarval

Bothus, the first from 26° 10′ N., 49° 00′ W. and the last from 26° 09′ N., 72° 47′ W. These 4 samples are also included in the Chart and in the main table (p. 107), but their main characteristics may be just briefly noted here.

Only one species is represented, as can be seen from the number of vertebrae:

	25	26	27
St. 677.....	2	3	
678.....	1	12	2
679.....	5	9	3
680.....	24	84	13
	32	108	18

It will be seen, that this is in full agreement with the results already discussed for the species *Bothus atlanticus*, which, as shown, belongs to the Sargasso Sea and spawns there. There is no mixing with any other species, 28 caudal vertebrae, for example, does not occur, and the remarkable uniformity with the previous records is a very sound confirmation of the independence of this Sargasso species.

The sample from St. 680 has a special interest. It contains altogether 322 specimens, from which a chance sample of 121 specimens gave the result recorded above. This is an enormous number, when we consider, that the haul is made from the deck of a steamer with a small net fishing only 40 mins. The position of the station was 72° 47′ W., thus further west than any of the previous records of *B. atlanticus* and, one would imagine, more within the Gulf Stream than the Sargasso Sea. It might be thought, therefore, that these specimens have been carried from the direction of the West Indian Islands, but there are one or two facts against this. In the first place, the hauls made in the neighbourhood of the West Indian Islands (stations 273, 394, 440, 441) gave only a small number of specimens (though also taken at the end of the year). Secondly, a very large number of specimens were also taken at St. 439, lying to the N. E. of the West Indies and, as shown previously, on the southern boundary of the Sargasso Sea, thus probably under the influence of the North Equatorial Current, which runs from east to west or north-west (thus towards and not away from the West Indian Islands).

Hence, other explanations must be sought for. There seem to be three possibilities, which would explain the occurrence of this enormous number of postlarval *Bothus* at St. 680. Either, they have come under the influence of the Gulf Stream and have thus been carried from the Gulf of Mexico. Or, they may have been spawned and grown up in the waters where they were taken, in which case they were still within the Sargasso Sea. Or, thirdly, they have been carried by the North Equatorial Current along the southern boundary of the Sargasso Sea past (i. e. outside of) the West Indian Islands into a kind of pocket at the western end of the Sargasso Sea. For reasons already stated, it is impossible to believe, that the postlarval specimens of *B. atlanticus* taken out in the middle of the Atlantic have been carried from the West Indies or the American coast. But it is not excluded, that the same species may live inside the fringe of islands, in the Caribbean Sea, namely, and the Gulf of Mexico. It would thus be of interest to obtain samples from these waters.

Subfamily SOLEINAE

The soles belong properly to southern waters, only 3 species, so far as known, occurring in the North Sea and further north, namely, *S. vulgaris, S. variegata* and *S. lutea,* and it is only of these 3 species that we know the postlarval stages. All the known European species, however, occur in the Mediterranean and adjacent waters. As the "Thor" has not had the good fortune to capture complete series of any of the species during the Mediterranean cruises, the difficulty of determining the few isolated specimens that came into my hands may well be imagined. There is, further, the important question, how many species of *Solea* are there in European waters? If the characters of the adults are only known imperfectly, it goes without saying, that the postlarval stages cannot be properly identified. My first task, therefore, was to ascertain the probable number of good species in European waters and thence, as far as possible, the characters of use in determining the postlarvae. The search through the literature thus necessitated has resulted in not a few surprises and it may be of use for the further study of this important group, if I give here a brief review of the different species, or what is known regarding them, even though my notes, admittedly, can only be imperfect. My material of the adults is not sufficient for a more detailed description, but in some cases I have been able to supplement my own notes by figures from earlier authors and these may be of assistance in the future work of distinguishing the different species. It would be of great interest and importance, if a collection of soles could be made at different places in the Mediterranean and Atlantic, so that the limits of variation of the different species can be determined.

The most natural grouping of the soles would seem to be, in the first instance, according to the nature of the anterior nostril of the blind side. This may be simple and inconspicuous (*Solea*) or enlarged, either elongated and tubular with few and small fringes at the lumen or short and broad, rosette-shaped with many radial folds in the lumen (*Pegusa*). This slight alteration in GÜNTHER's classification brings *S. Kleini* into the second group, to which it seems most naturally to belong. The first group contains a number of fairly well-known forms which may, though with difficulty, be further subdivided into 3 subgenera according to the varying stages of degeneration of the pectorals, decreasing number of vertebrae and the increasing villous nature of the scales (compare the series *Rhombus, Lepidorhombus, Scophthalmus* and *Zeugopterus*). On this basis we may construct the following classification, which may also serve to indicate the points requiring further investigation.

A. Anterior nostril of blind side short and narrow, not conspicuous (*Solea*).
   a. Pectoral fins of both sides almost equally developed, comparatively large, that of blind side not vestigial.
      1. D. 84—95; A. (71)74—78; Vert. 50—52? — *S. angulosa* Kaup.
      2. D. 73—84?; A. 61—72?; Vert. 48—50. — *S. vulgaris* Quens.
      3. D. 74—84; A. 61—77?; Vert. 48—50? — *S. azevia* B. Capello.
      4. D. 65—70: A. 50—58; Vert. 37. — *S. ocellata* L.
   b. Pectoral of blind side vestigial (*Microchirus*).
      5. D. 80—92; A. 65—76; Vert. 44—45. — *S. capellonis* Steind.
      6. D. 63—77; A. 46—61; Vert. 38—41; conspicuous black transverse bands. — *S. variegata* Don.
      7. D. 65—77; A. 50—63; Vert. 38—39; faint dark markings with streaks on D. and A. — *S. lutea* Risso.
   c. Pectoral fin of blind side absent (*Monochirus*).
      8. D. 52—61; A. 40—49; Vert. 34. — *S. monochir* Bonap.

B. Anterior nostril of blind side broad, rosette-like with many radial folds in lumen or elongated and tubular (*Pegusa*).

9. Anterior nostril of blind side only of moderate breadth, tubular, with small fringes or papillae round the opening; right pectoral with black spot in centre or near base; colour gray with black band round D. and A.
D. (74)80—91; A. 59—70; Vert. 47—48. *S. Kleini* Risso.

10. Anterior nostril of blind side broad, rosette-like; black spot on right pectoral on posterior half; colour fawn speckled with dark.
D. 79—89; A. 61—70; Vert. 47—48. *S. lascaris* Risso.

11. Anterior nostril of blind side very broad, rosette-like, overlapping mouth; black spot on right pectoral on posterior half; colour chestnut to dark brown, mottled with black.
D. 69—76; A. 54—61; Vert. 42—43. *S. nasuta* Pallas.

According to this list[1] there should be some 11 species of *Solea* in European waters. Of these *S. angulosa*, *S. vulgaris* and *S. azevia* have not been properly distinguished. On the other hand, we have the *S. minuta* of PARNELL (1837), which STEINDACHNER considered a good species; also, the various forms usually referred to *S. lascaris*, namely, *S. impar*, *S. aurantiaca* etc.

The total number of postlarval soles taken by the "Thor" on its Mediterranean cruises amounts only to 14 specimens. This may be due to the special habits of the postlarval soles and to the fact, that the "Thor" restricted its investigations almost entirely to the deep-sea areas remote from the coasts. The specimens make up in interest what they lack in abundance.

1. SOLEA ANGULOSA Kaup.

Pleuronectes solea Linné 1756 (partim).
Solea angulosa Kaup 1858.
Solea vulgaris Brito Capello 1867.
Solea angulosa Fage 1912.

D. 84—95; A. (71)74—78; Vert. 50—52? Scales l. tr. 50/56; l. l. 156—162.

It has been accepted generally, that the *Solea vulgaris* of QUENSEL was the same as LINNÉ's "*Pleuronectes solea*" and though European authors have been content to omit any reference to LINNÉ, the American authors JORDAN and GOSS have preferred to revive the specific name of LINNÉ and refer to the "common sole" as "*Solea solea*". As a matter of fact, however, LINNÉ had probably two species under his "*solea*"; at least, for his first specimen (from ARTEDI) he gives D. 91, A. 74, whereas in a second specimen from Bohuslän he found D. 71, A. 40! The American authors give D. 73—80; A. 61—69.

BLOCH (1782—84) and QUENSEL (1808) had evidently the true common sole and the latter gave it its Latin name. Since then the majority of the records "*S. vulgaris*" seem clearly to refer to one and the same species, the common sole — or what we believe to be the common sole — but some undoubtedly refer to ARTEDI's species or a mixture of both.

In 1858 KAUP established what he supposed to be a new species, nearly related to *S. vulgaris* but

[1] Through the kindness of Dr. JOHS. SCHMIDT, I have been able to see the work of GUICHENOT on the fishes of Algiers (Exploration scientifique de l'Algérie pendant les années 1840, 1841, 1842. Paris 1850). In this some 8 species of *Solea* are referred to, but apart from the colouration no descriptions are given. It is of interest to note, however, that GUICHENOT mentions "*Solea cinerea*, Val. Coll. mus.", which is said to have been confused with *Soela vulgaris*, "*Solea luctuosa*, Val. Coll. mus." a highly coloured sole and also "*Pleuronectes angulatus*". The remaining 5 species can be referred to the corresponding species in the above list, but I am unable to locate these three exactly. *S. cinerea* may have been *S. azevia* Cap., *S. Capellonis* Steind. or *S. angulosa* Kaup; *S. luctuosa* was possibly *S. Kleini* or *S. nasuta* and "*P. angulatus*" may have been *S. angulosa* Kaup. Without direct investigation of living specimens it is impossible to say, how far these names affect the synonymy given in the text.

with longer pectorals. Like all his other descriptions his diagnosis is extremely meagre and his species, for this good reason, has not hitherto been recognised. There are possibly other references in the literature which may apply, under a different name, to KAUP's species, but the one which appears to me the most certain is the "*Solea vulgaris*" of BRITO CAPELLO (1867). We have here a species, which CAPELLO himself thought somewhat divergent from the records given by other authors, though he only specified the number of fin-rays. It seems to me remarkable, also, that other authors have not had their suspicions roused with regard to the apparently great variation in the number of fin-rays which has been credited to "*S. vulgaris*". The following are a few of the records:

apparently *S. vulgaris*	D.	A.	apparently *S. angulosa*	D.	A.
BLOCH	80	65	LINNÉ	91	74
QUENSEL	72	62	KAUP	84	71
RISSO	81	61	B. CAPELLO	85—95	74—78
BONAPARTE	81	67			
CANESTRINI	80—84	67—73			
GÜNTHER	73—80	61—69			

If we were to consider all the records as belonging to one and the same species, we should have the range of variation noted by EHRENBAUM (probably as a compilation): D. 70—97, A. 54—83. From what has been shown above under *A. laterna*, the variation in the number of fin-rays in flat-fishes may certainly be very great in a few cases, as much as 17—18 rays; here, however, the range is more nearly 30 rays. This in itself would seem to indicate the presence of at least 2 species. Among other authors who may perhaps have included this species under *S. vulgaris*, we may note HOLT and BYRNE's reference to *S. vulgaris* with D. ca. 75—90, A. ca. 65—80, but this may also have been merely a compilation from other authors.

To L. FAGE (1912) is due the credit of having resuscitated KAUP's *S. angulosa*. The principal distinctive characters noted by him are; pectorals of equal length half as long as the head[1] (in *S. vulgaris* and *S. azevia* they are only ca. 40 % of length of head), caudal fin contained about 7 times in total length (in *S. vulgaris* about 9 times, in *S. azevia* about 6 times) and the higher number of fin-rays noted.

According to the records, *S. angulosa* appears to occur in the Bay of Biscay (KAUP), south-west of Ireland (?), on the coast of Portugal (BRITO CAPELLO) and in the Mediterranean to Algiers (KAUP, FAGE).

2. SOLEA VULGARIS Quensel.

Solea vulgaris Quensel 1808, Bonaparte ca. 1833, Canestrini 1861, Günther 1862 etc.

D. 73—84?; A. 61—73?; Vert. 48—50. Scales l. tr. 45/55?, l. l. 130—160?

As *S. vulgaris* has been confused apparently with both the preceding and the following species, its specific characters require revision. Combining the records noted above from CANESTRINI and GÜNTHER, we have D. 73—84, A. 61—73, which may possibly represent the range of variation in the number of fin-rays, but further investigation is required.

Of *S. vulgaris* the "Thor" has taken 4 postlarval specimens, all 4 at the same station (St. 38) on January 31st 1909. Their lengths lay between 7 and 8·5 mm. Assuming 6—8 weeks for the embryonic and larval development this would place the spawning time in November—December. GRAEFFE (1888) gives January and February for the Adriatic; MARION (HOLT) took the eggs in February at Marseilles and CUNNINGHAM also found them in February at Plymouth; HOLT and BYRNE give March—April to June as the spawning time for British and Irish waters and EHRENBAUM April to August, principally second half of May, for the North Sea. A very wide range for the spawning time is, of course, not unknown among flat-fishes, but these records would indicate, that *S. vulgaris* spawns nearly the whole year round within its region of

[1] "Die Brustflosse gleich der Entfernung von der Wurzel der Brustflosse bis zum unteren Auge" (KAUP).

distribution. It may be recalled also, that the different authors who have examined the eggs give an extremely wide range for their dimensions.

All four specimens are more or less in process of metamorphosis, so far as the migrating eye is concerned, but in the smallest (7 mm.) the end of the notochord is only slightly bent upwards. The oldest (8·5 mm) agrees precisely, in position of the eyes, notochord and pigment with EHRENBAUM's description of a specimen 7·5 mm. long from the North Sea. As remarked specially by him, the air-bladder is comparatively small in this species. Both pectoral fins are pedunculated.

It may be remarked here, that CUNNINGHAM has also described a series of postlarval specimens referred by him to *S. vulgaris*. In the earliest stages (1891) he noted no air-bladder, in the later (1892), referred with doubt to *S. vulgaris*, he specially notes a large air-bladder. As EHRENBAUM remarks, this last specimen cannot belong to *S. vulgaris*; from the locality (Plymouth) and fin-ray formula there would seem to be no doubt, that this specimen belonged to *S. lascaris*. A similar specimen has been taken by the "Thor".

In the largest specimen of *S. vulgaris* taken by the "Thor", the number of fin-rays were D. ca. 83, A. ca. 65; the vertebrae numbered $10 + 40 = 50$.

3. SOLEA AZEVIA Brito Capello.

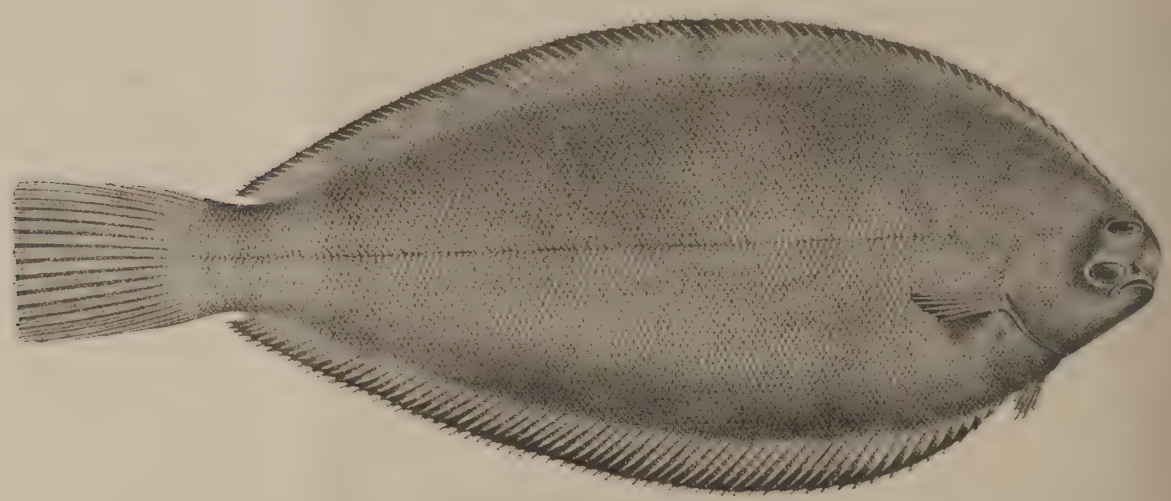


Fig. 18. *S. azevia*, from Steindachner 1868. $^2/_3$.

? *Pleuronectes theophilus* Risso 1810.

S. azevia Brito Capello 1867 with figure.

S. vulgaris var. *azevia* Steindachner 1868 with figure.

D. 74—84?; A. 61—77? Scales l. tr. 32/38; l. l. 118—126 (BRITO CAPELLO).

Though STEINDACHNER regarded this species as merely the younger stages of *S. vulgaris*, the clear diagnosis given by BRITO CAPELLO hardly leaves any doubt of the distinctness of the two species and his discrimination has been confirmed by BOULENGER (cf. HOLT and BYRNE 1905). CAPELLO notes as differences from *S. vulgaris*, that the dorsal and anal terminate at some distance from the tail, i. e. that the caudal peduncle is distinctly larger in *S. azevia* than in *S. vulgaris*; further, the tail is more square-shaped, less rounded at the end than in the latter. The colour is dark-brown to chocolate, with a dark yellow band along the outer part of the dorsal and anal fins; a black spot near the extremity of the right pectoral, but not so large (according to BOULENGER) as in *S. vulgaris*.

Pectorals 6—7/7—8; right pectoral about $^2/_5$ths the length of the head.

The species appears to be not uncommon; STEINDACHNER's specimens came from Lisbon, Cadiz, Gibraltar and Teneriffe.

In their review of the flounders and soles JORDAN and GOSS have placed RISSO's "*Pleuronectes theophilus*" under the second group of soles (*Pegusa*) and taken it as the prior name for *S. nasuta*. This procedure finds no justification in RISSO's description. Among the new species of Soles described by RISSO in 1810 were the two "*P. lascaris*" (No. 6) and "*P. Theophilus*" (No. 8). In the former the anterior nostril of the blind side is specially referred to, but there is no mention of it under "*P. theophilus*", so that we cannot place the latter in the *Pegusa* genus. "*P. theophilus*" may have been the young specimens (ca. 90 mm.) of *S. vulgaris* or of the present species, but the description is too imperfect to be relied on and the name should be dropped.

4. SOLEA OCELLATA L.

D. 65—70; A. 50—58; P. 6/7; V. 5/5; Vert. 9 + 28 = 37. Scales l. tr. 27/29; l. l. 70—75.

In this species the left pectoral is considerably reduced in size, being little more than half the length of that of the right side. It is thus a transitional form, but the left pectoral is nevertheless too well developed to allow the species to be relegated to the subgenus *Microchirus*, where this pectoral is vestigial with only 2—3 quite short rays.

This well-marked species is common in the Mediterranean to the east and south coasts of Spain and very common at Teneriffe (STEINDACHNER), but it is not mentioned from the coast of Portugal.

To judge from the number of fin-rays and vertebrae, the postlarval specimens of this species should be readily identified. The only other species with which it might possibly be confused is *S. lutea* (or *minutus*), the postlarval stages of which are well-known. The postlarval stages of *S. ocellata* are not present in my material from the Mediterranean.

5. SOLEA CAPELLONIS Steindachner.

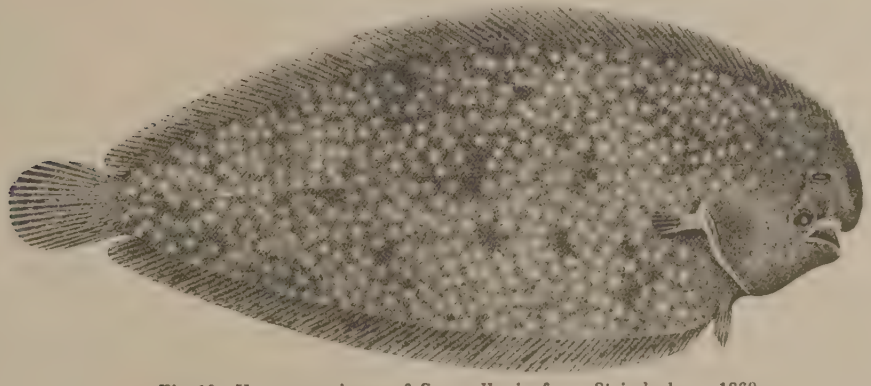


Fig. 19. Young specimen of *S. capellonis*, from Steindachner 1868.

S. capellonis Steindachner 1868, with figure.
S. profundicola Vaillant 1888. Holt and Byrne 1905, with figure.
S. Greeni Günther 1889.

D. 80—92; A. 64—76; Vert. 43—44. Scales l. tr. 30—35/34—42; l. l. 125—150.

On comparing Steindachner's diagnosis and figure of this species with Holt and Byrne's description of *S. profundicola* Vaillant, or the description of Vaillant, it seems to me, that the resemblances outweigh the differences and that we must provisionally take them to be one and the same species. The fin-ray formulae and scales given by these authors are as follows:

	D	A	Scales	Vert.
Steindachner.....	80—92	64—76	128—150	
Vaillant.....	84	69 +	127	8 + 34 (without hypural)
Holt and Byrne...	ca. 80—90	ca. 65—75	125—140	

The colouration light brown or fawn, with pale spots and dark shadings (Steindachner), pale roundish areas disappearing on preservation (Holt and Byrne). The tip of the right pectoral is said to be black by Steindachner. This is not mentioned by Vaillant or Holt and Byrne. The pectorals are very liable to injury, however; in well-preserved specimens of *S. variegata* and *S. lutea*, for example, the right pectoral always has a well marked black spot on the distal half. This is not mentioned either by Holt and Byrne, nor represented in their figures. Vaillant admits, that all his specimens were in a bad condition when examined, except one; this one does not seem to have been very perfect either. The same reason, injury or bad specimens, probably explains also the difference in the statements with regard to the length of the pectorals. Steindachner states, that these are about equal in size on both sides and about $3^1/_2$ times in the length of the head; Vaillant states, that this species belongs to the group *Microchirus* and Holt and Byrne, that the pectoral of the ocular side varies in length in different individuals, never much exceeding the eye in length (i. e. 4 to $4^1/_2$ times in head), the pectoral of blind side vestigial. These differences, if not due to injury as suggested, would certainly indicate, that *S. capellonis* and *S. profundicola* are different species, but as the number of fin-rays and scales are the same, the positive evidence of Steindachner has greater weight than the somewhat imperfect evidence of Vaillant and Holt and Byrne.

S. capellonis was obtained by Steindachner at Gibraltar and Dalmatia; his 7 specimens were from 5—6 inches long. Holt and Byrne summarise the distribution of "*S. profundicola*": "an inhabitant of deep water, and its known range extends from the S. W. of Ireland to a little south of the Canaries, and vertically from 135 to 750 fathoms". The statement that the number of vertebrae is 44 (without hypural, 45 with hypural) is taken from Vaillant. With regard to the colouration, it may be mentioned, that Steindachner suggests that this may be more uniform in the older specimens. The specimen figured by Holt and Byrne was larger and apparently more uniformly coloured than the specimen figured above, which is from Steindachner. Bourne (1890) states that a fresh specimen of "*S. Greeni*" 18·8 cm. long was a uniform chestnut brown.

The 2 postlarval specimens relegated here are 8 and 9 mm. long and still symmetrical. There are well-marked bars of pigment on the dorsal and anal fins (text-fig. 20) and the chromatophores have a distinct tinge of dark-brown or orange. The figure will show the distribution of the chromatophores without the necessity of further description. The 9 mm. long specimen has D. ca. 78, A. ca. 64 and the number of vertebrae is distinctly $9 + 35 = 44$. An air-bladder is present but is not large.

With regard to the parentage of these specimens, none of the well-known species would seem to make any claim to them. *S. vulgaris*, *lascaris* etc. all have a higher number of fin-rays and vertebrae, whilst *S. variegata* and *lutea* have a much lower number. The only other recognised species, which comes anywhere near to the values noted, is *S. nasuta*, which has a slightly smaller number of fin-rays and vertebrae. Besides, my material contains 3 other postlarval specimens, which claim to be *S. nasuta* and which differ considerably from the present specimen (comp. figs. 35 and 40). Excluding *S. nasuta*, therefore, the above scheme (p. 115) shows, that there is no other species of *Solea* yet known to which we can refer the present specimens but *S. capellonis*.

With regard to the particular postlarval form in question here (caudal vertebrae 35), it may be mentioned, that RAFFAELE (1888) has also obtained it at Naples ("sp. A"). I give here a figure of a later stage (11 mm.) also taken in the Gulf of Naples in November. The 9 mm. long specimen was taken in June at St. 107, thus about 100 miles east of the Straits of Gibraltar and the 8 mm. specimen in September at St. 218, off Algiers. When we remember how few postlarval specimens of any *Solea* species have been taken in the Mediterranean, it seems reasonable to conclude, that this species will prove to be not uncommon there as well as in the adjacent waters of the Atlantic.

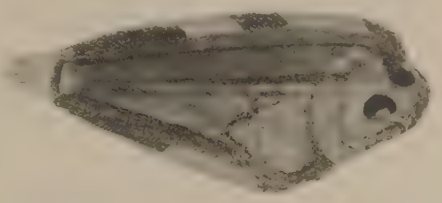


Fig. 20. ? *S. Capellonis* Steind. 11 mm. × 6. Naples, 2—XI—99.

Since the above was written, 2 specimens in precisely the same stages as described and figured above have been received from Monaco, through the kindness of Dr. RICHARD. The one is 9 mm., the other 10 mm. (spirit). In these D. ca. 75, A. ca. 60—61 and the caudal vertebrae in the larger specimen number 34 or 35. These specimens added to those recorded above, show that this species must be of fairly common occurrence in the Mediterranean. They naturally throw no further light on the question, whether all the specimens belong to the deep-water *S. capellonis* or to *S. nasuta* (or perhaps another species at present regarded as doubtful, e. g. *S. impar* or *S. aurantiaca*[1]). This question can hardly be settled until the adults have been reexamined or until a complete series of metamorphosing stages has been obtained. The above determination, as shown, rests mainly on VAILLANT's statement of the number of caudal vertebrae in his *S. profundicola*, but this may be erroneous, as the number of dorsal and anal rays given by HOLT and BYRNE for the latter species would correspond better with a species with a higher number of caudal vertebrae[2].

6. SOLEA VARIEGATA (Don.).

Pleuronectes variegatus Don. 1801.
Pleuronectes Mangilii Risso 1810.
Solea variegata Günther 1862 etc.

D. 63—77; A. 46—61; P. 3/4—5; V. 5/5; C. 18; Vert. 9 (10) + 29—31 = 38—41; l.l. ca. 100; l.tr. ca. 20/23.

As with *S. vulgaris* there seems to be a considerable amount of variation in the number of fin-rays for this species, as given by the different authors, and the range would be increased if we include RISSO's formula for "S. *Mangilii*" (D. 55; A. 50), which is supposed to have been this species. In 4 Mediterranean specimens I have found only a slight variation: D. 70—72, A. 55—57.

HOLT and BYRNE (1905) state, that the late metamorphosing stages of this species are distinguished by well-marked bars of black chromatophores, but, so far as I am aware, they have not yet described or figured

[1] GÜNTHER's species *S. aurantiaca*, which is generally supposed to be the same as *S. lascaris*, had 46 vertebrae (GÜNTHER 1862).

[2] Through the friendly efforts of Dr. SCHMIDT a specimen of HOLT and BYRNE's "*S. profundicola*" has been received from Mr. HOLT whilst the printing of this paper was in progress. It was 20 cm. long and had D. 86, A. 68; as HOLT and BYRNE remark, the colouration has become almost uniform on preservation, but traces could still be seen of dark and light spots. The pectoral fins are distinctly small, this being the only apparent difference from STEINDACHNER's *S. capellonis*. As suggested in the text above, the number of caudal vertebrae is higher than that given by VAILLANT for his "*S. profundicola*", namely 37 against 34 or 35 (HOLT and BYRNE do not state the number of vertebrae in their work on the Soles). The number of vertebrae in this specimen adds to the doubts expressed in the text, namely, (1) whether VAILLANT's statement of the number of vertebrae in his species was correct and, if so, whether his species is the same as HOLT and BYRNE's *S. profundicola* (GÜNTHER's *S. Greenii*); (2) whether STEINDACHNER's *S. capellonis* is the same as the *S. profundicola* of these authors; (3) whether the postlarval specimens described above under *S. capellonis* (a determination based on VAILLANT's statement of the number of vertebrae) really belong to that species. On the whole, I am disposed to believe, that the 11 species of *Solea* included in the above summary do not exhaust the number of European Soles.

these stages. Meanwhile, PETERSEN (1909) has described a series of postlarval stages (7 to 18 mm.) which he has ascribed to *S. variegata*. His specimens were remarkable in various ways, being uniformly covered with small dots of pigment, without arrangement into bars and they were mostly taken over great depths (1000—4000 meters), only a few in the western part of the Channel and at one single station north of the Hebrides.

Whilst one would be inclined to doubt this identification of these larvae, seeing that *S. variegata* is distinguished by its bars of pigment and also is not uncommon in the western part of the Channel at no great depths, it is difficult to gainsay the evidence brought forward by PETERSEN. The number of vertebrae and fin-rays in his series agree perfectly with those known in *S. variegata*, the only other known species which can come into consideration being either *S. azevia* or the problematic *S. minuta*, since the postlarval stages of *S. lutea* are already well-known. We do not know the number of vertebrae in *S. azevia*, but BRITO CAPELLO gives for the fin-ray formula: D. 74—84, A. 61—67. PETERSEN gives for his postlarval specimens D. 71—76, A. ca. 46—60. For the latter to agree with the former, we should have to assume, that BRITO CAPELLO made a mistake in the number of anal rays. On the other hand, if *S. minuta* is a species distinct from *S. lutea*, these specimens referred to *S. variegata* might also belong to *S. minuta*.

My material contains one specimen which also belongs to the series described by PETERSEN and with him I refer it to *S. variegata* (fig. 36). This specimen was taken at St. 183 in the Gulf of Salamis, thus far removed from the localities where PETERSEN's were taken. There can hardly be any doubt of its identity with the latter. It is only 7 mm. long and the fin-rays can only be counted approximately; it has D. ca. 74, A. ca. 54. After staining and clearing, the number of vertebrae is quite definitely 10 + 30, thus the same as PETERSEN's specimens. The pigmentation is also the same, except that in my specimen the pigment appears as small, stellate chromatophores, in PETERSEN's as tiny dots — a matter probably of condition. The most striking resemblance is, however, the absence of an air-bladder. In the species of *Solea* yet known and in all the forms to be described below, there is always an air-bladder.

There are one or two peculiarities in my specimen which are not mentioned in PETERSEN's description. In the first place, the pigment is stronger on the left (future blind) side of the body and it has a light-yellow tinge. Secondly, the body is much deeper, as if more compressed and thus in a more advanced stage than the corresponding stage figured by PETERSEN. A similar condition has also been noticed in the Mediterranean specimens of *S. lutea* by comparison with the northern specimens. Lastly, the abdomen is very large and protruding, owing in part to the fact, that the stomach and intestines are filled with copepods. Many of the northern specimens in the earlier collections of the "Thor" also have a very protruding abdomen.

According to the above records, the distribution of *S. variegata* extends from West of Scotland and the Channel down into the Mediterranean, Italy and as far as the Aegean Sea.

7. SOLEA LUTEA (Risso).

Pleuronectes luteus Risso 1810.
Solea lutea Günther 1862 etc.

D. 65—77; A. 50—63; P. 3/4—5; V. 5/5; C. 18; Vert. 9 (10) + 29—30 = 38—39; l. l. 62—72; l. tr. 19—22/20—25.

My Mediterranean specimens of this species show a good deal more pigment than is figured by HOLT and BYRNE, being in better agreement with the figures and description of CANESTRINI (1861) and the description of STEINDACHNER. Every third-fourth ray of the dorsal and anal rays has dark pigment, alternately at the base and at the tip. Further, there is a black spot on the membrane of the right

pectoral distally, just as is the case more or less in all other *Solea* except *S. Kleini*. Lastly, the dark markings on the right side are fairly distinct, 9--10 broad spots in a longitudinal row dorsally near the interspinous region, a similar row near the ventral interspinous region and 4—5 larger spots along the lateral line, the 4th, one-third of the distance from the tail, being the longest.

Only 3 postlarval specimens of this species have been taken by the "Thor" in the Mediterranean. The lengths are 4·5, 5 and 6·2 mm. In spite of this small size the vertebrae can readily be counted after staining, even in the smallest. The number in the two smallest was 10 + 29; D. ca. 72—75, A. ca. 54—56. At 5 mm. already the eyes are asymmetrical. In EHRENBAUM's specimens metamorphosis did not begin until a later stage (7 mm.), but this difference is most probably due to my specimens having shrunk in formaline; EHRENBAUM's measurements are of fresh specimens.

As my largest specimen represents an interesting stage not shown by EHRENBAUM, I give here a figure of it (fig. 37). It has D. 75, A. 55, vertebrae 10 + 29 = 39. Its length is 6·2 mm. and it is about halfway through metamorphosis. Though smaller than either it is intermediate between EHRENBAUM's fig. 33 and fig. 34 (1897). The pigment is essentially the same as in EHRENBAUM's figure 65 f (1905); the only difference worth noting is, that the breadth is very much greater than in EHRENBAUM's figures, the abdomen (without fins) being more than 40 % of the total length, whereas in the latter this breadth is only about 30 %. A similar difference in breadth between Mediterranean and northern specimens has been shown under *S. variegata*.

The air-bladder is of moderate size to large; the ventrals have just begun to appear; the end of the notochord is bent upwards and almost enclosed; 17—18 rays can already be counted in the caudal fin which arises almost in direct continuation of the dorsal and anal fins.

S. lutea is distributed from the Skager Rak and Kattegat along the west coasts of Europe to the Eastern Mediterranean. A very large number of specimens have been taken on the earlier cruises of the "Thor" (1905—06) in the Skager Rak, North Sea and Channel.

Regarding *S. minuta* I have only to point out, that STEINDACHNER expressly distinguishes this species from *S. lutea* by the higher number of fin-rays (D. 72—79, A. 56—62 in *minuta*), the higher number of scales along the lateral line (112—118 in *minuta*), as also by the common names used at Cadiz (Acedia for *lutea*, Golleta for *minuta*). In view of STEINDACHNER's accuracy in such details, it seems to me, that the question remains open, whether *S. minuta* is distinct from *S. lutea*.

8. SOLEA MONOCHIR Bonap.

Pleuronectes pegusa Risso 1810.
Monochirus hispidus Rafinesque 1814.
Solea monochir Bonaparte 1833?, Günther 1862 etc.

D. 52—61; A. 40—49; P. 0/5; V. 5/5; Vert. 9 + 25 = 34; l. l. 60—64; l. tr. 19—21/27—29.

This species should rightly be called *S. pegusa*, for there can be no doubt, that RISSO's "*P. pegusa*" is this species, as he rightly states, that it has only one pectoral with 5 rays. LACÉPÈDE it is true, had earlier (1803) used *pegusa* for another species, but as the latter species already had a name, *ocellatus*, *pegusa* was free to be used in RISSO's sense. As a specific name, however, *pegusa* has long been extinct; the choice is usually *S. monochir* or *Monochir hispidus*. In following GÜNTHER and STEINDACHNER and choosing *S. monochir*, we give the species a name which expresses its salient systematic features without implying generic rank, to which the characteristics are not entitled.

For this species Canestrini gives D. 56—61, A. 44—49; Jordan and Goss D. 51, A. 41. In 3 specimens I find 55—56, A. 40—44 and the number of scales as stated above (Jordan and Goss give l. l. 54).

From its low number of vertebrae, this species should be readily recognised in the larval and postlarval stages; no specimens have been taken by the "Thor".

Steindachner states, that this species is very common on the east and south coasts of Spain to Cadiz and the Italian authors give it as common there; habitat seaweed among rocks.

The genus *Pegusa* also has its difficulties. According to some authors it should contain 4 to 5 species, others however reduce the number to at most two, but in no case, except perhaps Steindachner, has any representative material been collected from different places. Until that has been done and the descriptions of the original species compared, it will not be possible to settle, how many species there really are. I have examined adult specimens of 3 distinct species and the postlarval material collected by the "Thor" contains apparently only 3 species, which can be referred to this genus, to judge from the large air-bladder and fin-ray formula etc., so that the existence of so many distinct species is certain.

Of the postlarval stages we know nothing for certain as yet. Raffaele (1888) and Holt (1891) have described the early larva of a Sole with a large protuberance above the head, which the latter author has identified with *S. lascaris*. But the only reference to the later, postlarval stages is Cunningham's description of a specimen (1892) which he referred to *S. vulgaris* with doubt, but which must in reality belong to *S. lascaris*.

With the determination of the adults in an uncertain condition and the postlarval stages practically unknown, one cannot guarantee any very great reliability in the identification of a few isolated specimens, but I do not think, that the following determinations can be very far wrong.

SOLEA KLEINI (Risso).

Fig. 21.
S. Kleini, from Bonaparte 1832—41.

Fig. 21 a.
Obverse side of head (original).

(*Rhombus Kleinii* Risso 1826).
Solea Kleini Günther 1862, Steindachner 1868 etc.

D. (74) 80—91; A. 59—70; P. 9/9; V. 5/5; Vert. (9) 10 + 38 = 47—48; l. l. 100—110.

Günther did not include this species under his genus *Pegusa*, but there is a wider distance between the inconspicuous, tumid nostril of the *Solea* genus and the elongated tubular nostril of *S. Kleini* than between the latter and the rosette-shaped nostril of *S. lascaris* and *S. nasuta*, and I follow the American

authors in placing *S. Kleini* under the genus *Pegusa*. The tube of the nostril is not fringed but at the summit there is a ring of small fringes or papillae. Behind the nostril is a groove or pit free of the fringes which cover the blind side of the head anteriorly, and the nostril, in preserved specimens, is depressed into this smooth groove.

Jordan and Goss follow Steindachner in stating, that the scales of the blind side are cycloid, but Steindachner made the reservation: "doch wäre es nicht unmöglich, dass die zarten Zähnchen am hinteren Rande im hoheren Alter verloren gehen". In a specimen 108 mm. long the scales of the blind side are distinctly ciliated except in the middle of the fish, where presumably they are most exposed to rubbing. I have found the same condition in a specimen of *S. nasuta*, so that *S. Kleini* cannot be taken to be an exception to the rule, that all the *Solea* (of Europe) have ctenoid scales on both sides of the body. In *S. Kleini*, however, the ciliation is very slight, quite unlike what we find in *S. lascaris*, for example.

The pigmentation of this species is characteristic, with a broad black band round the dorsal and anal fins. The black colouration is also present on the ventral surface of the ventral fins. The black spot on the upper pectoral lies near the base and not towards the tip as in the other species of *Solea*.

For the number of fin-rays we have:

	D.	A.
Risso	86	68
Bonaparte	80	64
Canestrini	80—91	64—70
Steindachner	74—82	59—64

According to Jordan and Goss, the number of vertebrae is $10 + 38 = 40$.

From the summary given above of the fin-ray formulae, it will be seen, that *S. Kleini* and *S. lascaris* have precisely the same numbers and thus cannot be distinguished from one another in the postlarval stages by this means. As it happens there are two specimens in the collection of the "Thor", which have the same number of vertebrae ($9 + 38$) and the same fin-ray formula, but which seem to belong to two different species. To aid in distinguishing these 2 specimens we have only the postlarval specimen described by Cunningham in 1891 from Plymouth, which does not belong to *Solea vulgaris* but to this genus and which, to judge from the locality where it was taken, must belong to *S. lascaris*. The only other species that can come in question is possibly *S. azevia*, but this is a much rarer species, at least in the Mediterranean and Channel, and its postlarval stages have probably a small air-bladder (or one). Both the specimens in question here have a conspicuously large air-bladder.

One of the specimens agrees better with Cunningham's description of his specimen and for this reason I have placed it under *S. lascaris*. The differences between it and the specimen figured here lie almost entirely in the nature and distribution of the pigment and form of the snout.

The present specimen (fig. 38) is 7 mm. long and was taken at St. 93, thus near the southern end of Cadiz Bay. So far as can be seen from a preserved specimen (formaline) it has only black pigment in the form mostly of spots or irregular small stars. These are scattered irregularly over the head and body but are present in a denser mass at the posterior third of the body, especially ventrally. The base of the interspinous regions does not show a row of spots or dashes, such as we find in the other specimen. There is a distinct snout but the concavity between the snout and the beginning of the dorsal fin is not so marked as in the other specimen. The eyes are still symmetrical. The fin-ray formula is D. ca. 87, A. ca. 70. In front of the beginning of the dorsal fin there is a clear space or swelling over the mid-brain free of rays, which would seem to be the remnant of the larval prominence described by Raffaele and Holt. The specimen to be described under *S. lascaris* also has this same peculiarity, even more marked. Lastly, there is a large and conspicuous air bladder; the ventrals have not yet appeared.

It is not excluded, naturally, that the specimen described here may really belong to the same species as the one described under *S. lascaris*, but this, to my mind, would imply a greater possibility of variation in the pigment than seems probable. It is only a complete series, however, including the

metamorphosing and metamorphosed stages, which will be able to determine the matter definitely. It need hardly be said, seeing that the eyes are still symmetrical in both specimens, that the nostril of the blind side has not yet developed the characteristics of the adult.

With regard to the distribution of *S. Kleini*, STEINDACHNER records it from Barcelona and CÓMBIS (1868) from Minorca. It appears to be only moderately common on the Italian coasts (Naples, Messina, Venice).

SOLEA LASCARIS (Risso).

Pleuronectes lascaris Risso 1810.
Solea lascaris Günther 1862.
S. aurantiaca Steindachner 1868.
? S. lascaris — —
S. lascaris Holt and Byrne 1905.

D. 79—89; A. 61—70; P. 8/9; V. 5/5; G. 18; Vert. 47—48; l. l. 110—130; l. tr. 30—34/37—40.

As noted hy STEINDACHNER, it is probable, that BONAPARTE confused this species with the next (*S. nasuta*) and CANESTRINI admittedly did not distinguish between them. As will be noted below, however, it is even doubtful, if STEINDACHNER's identification of his *S. lascaris* was correct. For the fin-rays we have:

	D.	A.
RISSO	85	68
BONAPARTE	78	60
CANESTRINI	67—76	53—59
STEINDACHNER *lascaris*	80—89	61—68
STEINDACHNER *aurantiaca*	81—83	67—68
HOLT and BYRNE	79—89	67—70

In all the specimens of *S. lascaris* I have seen, both from the Mediterranean and Channel, the colouration is light brown or yellow with numerous small, dark spots (distinct even in spirit specimens) sown over the head and body. This is also the description given by RISSO: "couleur fauve tigré de noir" and by HOLT and BYRNE, who find, however, that the dark spots are liable to disappear more or less. On the other hand, the colouration in STEINDACHNER's "*S. lascaris*" was much darker and more uniform, each scale being ash-gray or blue-gray with dark-brown shade round the gray. Turning now to STEINDACHNER's description of "*S. aurantiaca*", we find the colouration "sehr schwach und undeutlich braun marmorirt und schwarz gesprenkelt oder punktirt" — which, of course, applies to the true *lascaris*. And regarding his "*S. lascaris*" STEINDACHNER himself says, that it agrees exactly with RISSO's *lascaris* in the number of fin-rays but "weniger in der Zeichnung des Körpers". The conclusion would seem to be inevitable, that STEINDACHNER was really dealing with a different species, which requires reidentification. His specimens came from Teneriffe, where it is said to be common.

Figure 39 represents the postlarval specimen I refer to *S. lascaris*. It is 8 mm. long with fin-ray formula D. 87, A. 70; the number of vertebrae is 9 + 38 = 47. It was taken in June at St. 107 about 100 miles from the Straits of Gibraltar and halfway between Spain and Morocco. The eyes are still symmetrical or nearly so. The concavity between the snout and the beginning of the dorsal fin is very marked. The air-bladder is very large; the ventrals have not yet appeared and the notochord is not yet completely enclosed.

What is most characteristic of this specimen is the pigmentation. It has a very large number of large, but exceedingly delicate, stellate chromatophores, strewn over the head, abdominal cavity and body. These even in formaline have a faint yellowish tinge, which deepens to orange or brownish orange in the denser mass over the air-bladder. On the dorsal fin the dark pigment specks are arranged chiefly in 3 bars; on the anal fin there is a greater accumulation of the dark specks opposite the last of the dorsal bars. There is a faint but distinct indication of a dorsal and anal row of dashes along the bases of the interspinous regions.

Cunningham (1891) has described a late postlarval or metamorphosing stage of what appears to have been *S. lascaris*. It was taken near Plymouth and was 11 mm. long; D. 86, A. 68. As it was not *S. vulgaris*, as already pointed out by Ehrenbaum, there is no other species but *S. lascaris*, occurring in the Channel, to which it could belong. It had a conspicuously large air-bladder. Cunningham gives the following description of the pigment: "The colouration is not reproduced in the figure; it consisted of black and orange specks (chromatophores) and more diffuse patches of lemon-yellow. — On the body and head the specks were pretty uniformly distributed, but on the dorsal fin there were three pigmented regions, one at the anterior end, one in the middle, and one near the posterior end. On the post-anal fin there was only one pigmented area of considerable extent, opposite the posterior area of the dorsal fin".

It seems to me, that this description may be taken to apply to the specimen figured here and the probability is thus very great, that this is an earlier stage in the postlarval development of *S. lascaris* than that described by Cunningham. As mentioned above, the question, whether the specimen described under *S. Kleini* with somewhat different pigmentation also belongs to this species, can only be determined when a complete series of postlarval and metamorphosing stages are available.

SOLEA NASUTA (Pallas)

Fig. 22. *S. nasuta*, from Algiers, n. s.

Fig. 22 a.
Obverse side of head, same specimen.

Pleuronectes nasutus Pallas (1811) 1831.
Solea lascaris (= *S. nasuta* = *S. impar*) Canestrini 1861.
Solea nasuta Steindachner 1868.

D. 69—76; A. 54—61; Vert. 42—43; P. 8—10/9; V. 5/5; C. 18; l. l. 113; l. tr. 29/36.

There would seem to be little reason for confusing this species with *S. lascaris*, as has been so frequently done. It has a spotty appearance, it is true, but the ground-colour is very much darker, to almost black and it has a much smaller number of fin-rays and vertebrae. The above diagnosis is based on 3 specimens and it agrees with the description given by Steindachner. Further, the expanded anterior nostril of the blind side is even larger in *S. nasuta* than in *S. lascaris*. My specimens are from Naples and Algiers. Steindachner states, that it is rare on the east coast of Spain. He had only one specimen from

Cadiz; 2 others were received from Constantinople and the Black Sea. PALLAS had his specimens from the Black Sea. Except in the dark colour and the fact, that STEINDACHNER also obtained the species from the Black Sea, there is but little to indicate, that PALLAS should be considered the founder of the species called here and by STEINDACHNER *nasuta*. In one specimen PALLAS found the fin-ray formula D. 48, A. 53, in another from Sebastopol D. 61, A. 51. The discrepancy in the number for the dorsal rays gives reason for supposing, that PALLAS did not lay great weight on accurate counting. STEINDACHNER's description, however, leaves nothing to be desired. He gives D. 75—76, A. 59—61. "Die Färbung der Augenseite ist blau-grau oder braun; zahlreiche schwarzliche Nebelflecken und kleinere weissliche undeutliche Flecken mit verschwommenen Randern liegen auf der rechten Körperseite". Except for the indistinct, whitish spots, it will be seen that this description agrees with the above figure of one of my specimens.

There are 4 postlarval specimens in the collections of the "Thor" from the Mediterranean, which might claim to belong to this species. Of these 3 form one series, the fourth belongs to a totally different species and has already been described under *S. capellonis*. The concavity between the snout and the beginning of the dorsal fin in the 3 specimens is not so marked as in the preceding 2 species. As this series comes nearest to what is known of the fin-ray formula and number of vertebrae in *S. nasuta*, and no other species known lays claim to it, there seems no reason for hesitating to refer the series to the present species.

In the smallest of the series (Pl. IV fig. 40) the fin-rays cannot be counted, but the caudal vertebrae number ca. 33. The largest specimen has 9 + 34, D. ca. 76, A. ca. 62. The pigment is not very regular or conspicuous, except along the base of the interspinous regions, where it is well-marked, and there is a very large branching chromatophore above the mid-brain as in *S. lutea*.

These 3 specimens were taken at St. 104 and 106 in the Mediterranean, about 100 miles east of the Straits of Gibraltar and not far from the south coast of Spain.

Family: CYNOGLOSSIDAE

Genus: SYMPHURUS

Symphurus Rafinesque 1810.
Plagusia Bonaparte 1833.
Plagiusa Bonaparte 1846.
Aphoristia Kaup 1858.
Ammopleurops Günther 1862.
Symphurus Jordan and Goss 1889; Tate Regan 1911.

Generic characters: Sinistral sole-like flat-fishes; no pectorals and no lateral line; ventral fin separate from the anal, developed on right or blind side only, with 4 rays; caudal fin more or less confluent with the dorsal and anal fins.

This remarkable genus is supposed to be represented by only one European species, the *Plagusia lactea* or *Ammopleurops lacteus* of authors, and this is supposed by the American ichthyologists to be the species vaguely defined by RAFINESQUE in 1810 under the name of *Symphurus nigrescens*. There appear to be two species of *Symphurus*, however, in the Mediterranean, and RAFINESQUE's diagnosis may refer to

either species or both (or neither). It may be remarked here also, that BONAPARTE (1833) did not think, that his species (*lactea*) could be the same as RAFINESQUE's *Symphurus nigrescens*, judging apparently from the colouration but RAFINESQUE's vague and useless description may have been responsible for his conclusion. The advantage, nevertheless, of using RAFINESQUE's name *Symphurus* for the genus, to which it certainly may be said to apply and for which it was intended, is, that it enables us to avoid the confusion surrounding the names *Plagiusa* or *Plagusia* (cf. BONAPARTE 1833 and 1846; JORDAN and GOSS 1889).

The specific names of the Mediterranean species require to be settled. RAFINESQUE's *S. nigrescens* cannot rank, for the reason mentioned above. The specific name given by BONAPARTE to the one species has been used (either as *lactea* or *lacteus*) by all European ichthyologists and may thus claim the right of usage as well as of priority, seeing that the species was sufficiently well-defined for the first time by BONAPARTE. A second supposed species is described by CANESTRINI (Fauna d'Italia) under the name of *Plagusia picta* A. COSTA and in A. COSTA's "La Pesca del Golfo di Napoli" both *P. lactea* and *P. picta* are mentioned. According to the description given by CANESTRINI *Sym. picta* is distinguished from *Sym. lactea* by being more elongated and by having smaller scales, but chiefly by the more mottled colouration. Unfortunately, however, neither the fin-ray formula nor the number of vertebrae are stated and later authors have been very sceptical as to the existence of this species. I have also been able to examine 2 specimens in the Copenhagen Museum, which answer to the description of *picta* given by CANESTRINI and have compared them with a number of specimens of *lactea*. My conclusion is, that CANESTRINI's description may apply to a colour variety of *lactea*. It is possible, naturally, that the description may also apply to another form, for the colouration in *Symphurus* is certainly very variable, but even in that case *picta* must be discarded, for the same reason that *nigrescens* is discarded — namely, because the original description is so imperfect, that it may apply to two species.

Meanwhile, two postlarval forms of *Symphurus* have been noted from the Mediterranean. As will be shown, these two forms are quite distinct and prove the existence of two species. The one postlarval form can be referred with certainty to *Symphurus lactea*. The other postlarval form has long been known under the name of *Bibronia ligulata* Cocco and it was described again by EMERY under the name of "*Peloria Rüppeli* Cocco". EMERY's mistake was pointed out by RAFFAELE (1888) and LO BIANCO has suggested recently (1908 a), that *Bibronia* really represents the larval form of a Pleuronectid "e propriamente del genere *Ammopleurops*". It is quite probable, that Cocco had the postlarvae of both species in his possession, for his description applies partly to the one and partly to the other, but his figure undoubtedly refers to the second species. For this second species therefore, it seems most appropriate to use Cocco's name *ligulata*.

In addition to the two Mediterranean species, my material also contains a single, postlarval specimen of an American species taken near the West Indian Islands. This specimen is in a transitional stage of metamorphosis and is thus of peculiar interest. Its fin-ray formula also is somewhat different from that of the American species described by the American ichthyologists, so that one more species may have to be added to this already rich genus.

The postlarval characteristics of the three forms dealt with here are so peculiar and have so much in common, that they may be taken as typical for the genus; it is possible, that the whole family of *Cynoglossidae* possess similar postlarval characteristics. Thus, the "*Solea sp.*" figured and briefly described by GÜNTHER (1887) can be recognised from its form, elongated first dorsal rays and protruding abdomen, as belonging to this family and probably even to the genus *Symphurus*. GÜNTHER's "*Synaptura sp.*" from the Pacific also belongs to this genus or family.

As will be shown later, these postlarval forms have an extraordinary resemblance to the young stages of deep-sea fishes, which are generally supposed to be far removed from the flat-fishes. EMERY, for example, included two specimens of *Sym. lactea* in his account of the developmental history of *Trachypterus taenia*. There would seem to be an even greater resemblance to the early stages of deep-sea gadoids.

Species: SYMPHURUS LACTEA (Bonaparte)

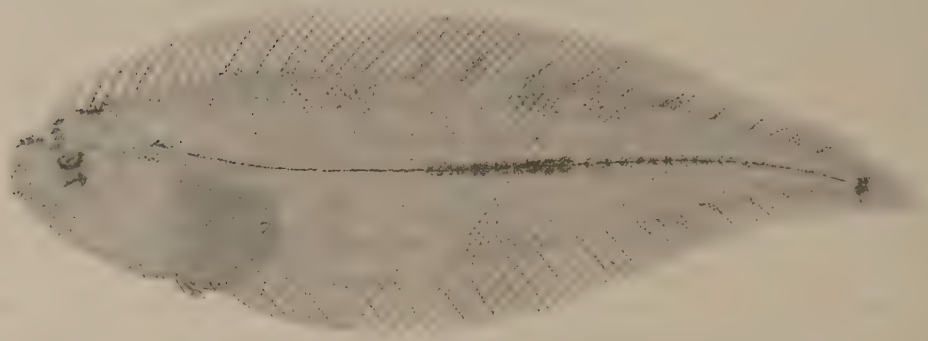


Fig. 23. Young specimen of *Sym. lactea* 27 mm. long. × 5.

? *Symphurus nigrescens* Rafinesque 1810.
Plagusia lactea Bonaparte 1833; Canestrini 1861.
Plagiusa lactea Bonaparte 1846.
Ammopleurops lacteus Günther 1862.
Plagusia picta A. Costa 1862 (Ann. del mus. zool. di Napoli); Canestrini (1871—72).

Postlarval stages:
Trachypterus taenia Emery 1883 (2 small forms).

D. + C. + A. = 84—91 + 12 + 71—78 = (160) 167—181; P. 0/0; V. 0/4. Vert. 9 + 39—41 = 48—50.

Adult characteristics: Form tongue-like, small, maximum length ca. 120 mm.; pointed at both ends, the anterior end the blunter. Eyes minute, contiguous, imbedded in the thick integument which surrounds the head and gill-covers. Dorsal fin beginning above the eye, the first 5—6 rays more apart than the others. Ventral fin along the ventral margin, small, the third ray reaching to the beginning of the anal; ventral and anal fins separate. By comparison with the total length the greatest height (measured just behind the abdomen and not including the fins) is 29—30 %, the length of the head (measured from tip of snout to upper end of branchial opening) 17—18 %. By comparison with the head the eye is 17—18 %, the lower jaw 26—27 % upper jaw (to end of snout) 29—30 %. Mouth subsymmetrical, the jaws on the under or blind side developed into a small bulla, bearing several rows of teeth; teeth on the upper (eyed) side in a single row. Snout well-developed. Scales small, roughly ciliated, about 75 in a longitudinal row from the head to the tail; no lateral line, but vagus nerve courses freely under the skin, first medially in the pectoral region, then curving dorsally and running longitudinally about halfway to the base of the dorsal fin to end a little way from the caudal fin[1].

The colour scheme falls into two varieties, a pale form and a banded form, with intermediate gradations. In the former, the body and head are almost uniformly grayish brown to brown, darker towards the vertical fins and on the abdomen, with very faint bars at the base of the fins. In the second variety, the ground-colour is lighter with about 6 broad but unequal bands on the body; these bands are most conspicuous towards the dorsal and ventral margins and are not continuous across the body, grading into the ground-colour about halfway towards the middle line. The dark tint of the bands is continued out on to the fins and when the fin-rays are folded back, these markings on the fins appear to form a continous, narrow, dark band round the body. The conspicuousness of these irregular bands depends, naturally, on the lightness of the ground-colour; when this is distinctly brown rather than grayish brown, the bands

[1] This peculiarity is shown very clearly in Bonaparte's figure of this species and can be noticed in specimens from which the scales have been for the most part rubbed off.

can barely be noticed and the two colour schemes thus merge into one another. When the scales are wholly or partly rubbed off, the bands are not seen and the colour becomes dirty gray.

Moreau (1881) states, that this is a rare species; at Banyuls on the south coast of France, I have found it fairly common. Bonaparte, who was the first to describe the species, evidently from the pale form with the scales mostly removed, states, that it is frequently sold at Rome with other "minutaglia"; this is also the case at Banyuls. As will be seen, the "Thor" has obtained a considerable number of postlarval specimens.

Again, Moreau states, that it has 2 ventral fins united in the middle line; Jordan and Goss (1889) say, that it has only one ventral, that of the left or eyed side; lastly, Tate Regan (1911) places the single ventral on the blind side. A simple dissection shows, that the last statement is correct; the pubic bone of the left side is present as a short splint only, whilst the pubic bone of the blind side has not only the ordinary expansion at the foot for the base of the 4 rays, but also a long, slender splint extending backwards along the ventral margin of the abdomen. As will be shown, this posterior process is represented in the postlarval specimens by a long, cartilaginous pubic bar, just as in *Arnoglossus* and *Bothus* (where, of course, there are two of these bars).

In the 2 specimens of "picta" contained in the Copenhagen Museum, which correspond exactly to the description of Canestrini, I have found the following number of fin-rays: D + C + A = 87 + 12 + 71 and 87 + 12 + 73 = 170 and 172. In 3 other adult specimens, which were not banded or only faintly so, the fin-ray formula is similar. The two distinctly banded specimens were smaller than the others (65 and 77 mm.) and it is worth noting, that Canestrini also states, that the form *picta* is smaller than *lactea*. It is probable, however, that as in the soles and other flat-fishes the colour changes with the nature of the bottom. In any case, the fin-ray formula associates these two specimens of "*picta*" with "*lactea*". The other species, *ligulata*, to be mentioned later, has quite a different number of rays.

Postlarval characteristics. From its earliest stages until metamorphosis the postlarval form of *Symphurus lactea* is torpedo-shaped, with but little resemblance to a flat-fish. The posterior part of the body, from the anus to the tail, is long and tapering, but is not conspicuously flattened from side to side. The anterior part of the body and the head diverge still more from the flat-fish type, the breadth or thickness being almost as great as the height: the head is comparatively short but very deep. Add to these characteristics the projecting abdomen, the long hammer-like pectorals, the anterior, elongated but not spinous, dorsal rays and the loosely-formed opercular apparatus covering over the bases of both pectoral and ventral fins (see figs. 41—43) and we have a postlarval form as widely different from a flat-fish as can well imagined. In fact, it is only the presence of all transitional stages from 6 mm. to metamorphosing and metamorphosed specimens of over 20 mm. in length, which enables the series to be definitely determined as belonging to this species of flat-fish.

The earliest stage in my material is already 6 mm. in length, but, as already mentioned, Emery (1883) describes a specimen only 3 mm. long (Taf. XVIII, fig. 1), which with another specimen of 6 mm. he refers to *Trachypterus taenia*. The figures are not good, but the peculiar appendix on the abdominal wall is distinctly shown; the abdomen projects well beyond the anal fins and the first rays of the dorsal are beginning to elongate. At 3 mm. there are only 3 rays longer than the others in the anterior part of the dorsal fin and they are not much longer; at 6 mm. these 3 rays are much longer and one or two more elongated rays are present behind the first 3. Further, Emery states in the text, though this is not represented in the figure, that there is a pigment bar across the tail and fins. Lastly, there was no ventral and the pectoral fins were large and pedunculated. It will be seen, that these characteristics agree precisely with the forms described here (cf. figs. 41, 42).

Fig. 41 represents the specimen of 6 mm. The head is drawn with the mouth open, to show a very distinctive characteristic of the group of flat-fishes, to which this species belongs, namely, the comparative absence of the opercular structures. This is conspicuous already at this early stage, the branchial apparatus being contained in a large, loose sac, which is held distended mostly by the long branchiostegal rays, 6 in number. This integumentary sac, within which in the adult the mouth, gill-arches, eyes and head are completely embedded, only covers the lower half of the head at this stage. This condition, therefore, may be regarded as the primary, the later condition, when the upper part, eyes, mouth (snout) etc. are embedded, as the secondary condition. Such is not the case in *Solea*.

Within this sac, which is closed below along the isthmus as far as the ventral fin, the glossopharyngeal and branchial apparatus have a large amount of freedom and as often as not the lower end is found lying freely in the sac, as shown in the figure. Further, it may be mentioned, that special stays or bony supports are developed all round the head for the support of this integument, thus, downwards from the mandible, a whole frame-work or lattice-work of stays over the head and the opercular bones are modified into a still more remarkable system of bony stays. These remarkable structures cannot be described in detail here and are only mentioned to explain, how this "round" fish of 6 mm. gradually transforms itself to a flat-fish.

At this early stage there are no teeth in the jaws; these appear about 12 mm. as a narrow row of 4 to 6 above and below, at the extreme end of the premaxilla and mandible. It will be noted also, that the mouth and head have rather the appearance of belonging to a species with wide gape from side to side and eyes approaching one another on the dorsal margin, as, for example, *Uranoscopus* or *Trachinus*. As will be seen, there is still another, very important developmental character, in which this form resembles *Trachinus* and differs from all other groups of flat-fishes.

The sac-like integument of the lower half of the head extends backwards also to cover the lower half of the clavicular arch (compare fig. 41, in which the gill-cover is drawn forward and downward, revealing the pectoral arch, with figs. 42, 43, which show the normal position of the gill-cover, concealing the pectoral arch and origin of the ventral fin). Even in the earliest stage (6 mm.) the pubic bones (or cartilage) are well-developed, dependent from near the end of the clavicles and one extends backwards as a narrow rod of cartilage along the ventral margin of the abdomen, just as in *Bothus* and *Arnoglossus*. The clavicles reach to the ventral margin of the body under the gill-cover and remain there permanently. In *Symphurus* the pubics occupy a similar position relative to the clavicles to what we find in *Pleuronectes*. But in the presence of well-developed pubics at this early stage (6 mm.) and in the appearance of the ventral fin, fully developed, at a little later stage (10 mm.) this form differs from *Pleuronectes* and all other flat-fishes, resembling here again the *Trachinidae*. The only ventral fin developed is that of the right side. That of the left side makes no attempt to develop, although the dependent pubic bone of that side is developed along with the other. It may be remarked, that the posterior prolongation of the pubic bone along the abdomen is only developed along the one side, the right, and this probably stands in connection with the development of the ventral fin of that side.

The pectoral fin is a fan-shaped organ supported on a large and arm-like peduncle (fig. 42). The latter is in fact the most conspicuous portion of the fin and becomes more so during postlarval development (fig. 43), the thin membrane surrounding it, which corresponds in reality to the large, embryonic pectoral of other flat-fishes, being comparatively broad in the early stages, but narrow in the later, until finally the club-shaped peduncle only remains (fig. 43) and it also is thrown off in the end (fig. 44).

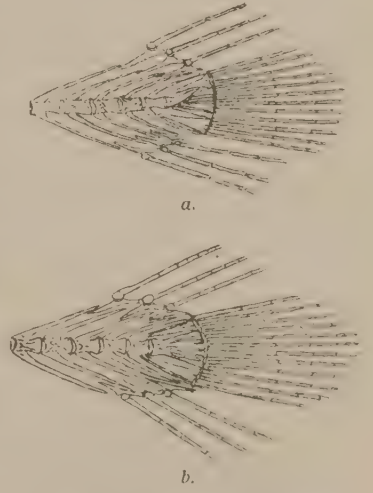
The dorsal fin in the earliest stages about 6—7 mm. begins above the mid-brain, thus well behind the eyes. The 2nd to 5th rays are already long; the first ray is short and inconspicuous and never attains the same length as the others. These 5 rays may represent the first, spinous, dorsal fin of the Acanthopterygians but they are not spinous; they (2nd—5th) are always wide apart and free at their ends (figs.

41—43). These rays cannot be homologized with the "tentacle" of *Arnoglossus* and *Bothus*; their origin and relation to the interspinous bones beneath being quite different. In the latter genera the "tentacle" arises from the longitudinal edge of the dorsal fin; such an origin is excluded in the case of the 5 rays of *Symphurus*. Again, the "tentacle" in the former is based on an interspinous bone similar in position, though larger, to the succeeding interspinous bones, but in *Symphurus* the interspinous bridge from the first neural spine to the tip of the snout is constructed on a totally different principle. *Solea* does not have this bridge, a single interspinous bone doing duty for the whole.

At 12 mm. the first 2 rays of the dorsal fin are directly over the eyes and the forward progress on the snout in continued just as in *Arnoglossus* and *Bothus*. But the fin never reaches so far forward as in the latter; the first dorsal ray has its permanent position just above the eye (figs. 44, 45); what does grow forward to the tip of the snout, is the interspinous bridge and the migrating eye comes through under the lattice-work of this bridge (fig. 44).

The caudal fin contains 12 rays and arises in the usual way, except that it makes its appearance much later than the other vertical fins (cf. figs. 41, 42). In this regard *Symphurus* differs from all other flat-fishes and again resembles *Trachinus*. In the earliest stages the notochord is quite straight, though the dorsal and anal fins are already fully developed. A little later, a thickening of the tissue underneath indicates the beginnings of the ural elements and the caudal rays; the notochord is still quite straight. At 10 mm. the notochord is bent up at a slight angle and the caudal fin with the ural elements is fully formed. It will thus be seen, that the caudal fin is independent and arises independently of the dorsal and anal fins. During development, however, the three fins gradually become more and more continuous, and it is of interest to note, how this is brought about. Further, I have shown in an earlier paper (1900), that the tail in the adult *Symphurus* (*Ammopleurops lacteus*) is completely diphycercal, but I was not able at that time, to explain how this condition had arisen. We can see this now from the present material and the two text-figures indicate sufficiently what occurs (text-figures 24 a, b).

In the beginning the urostyle (end of the notochord) is comparatively long in all flat-fishes and in all flat-fishes the change from the heterocercal to the homocercal form of tail is brought about by the reduction or resorption of the urostyle. In the adult flat-fish the urostyle is not to be seen and the last vertebra (so-called) is formed in reality of the fused ural elements, which form a broad fan-shaped bone showing merely the lines of fusion of the separate elements (cf. 1900, Pl. XI, where however *Rhombus maximus* and *Solea vulgaris* should be exchanged). In the earlier stages these separate elements can be distinguished.



a.

b.

Text-figure 24. Development of caudal fin and ural elements in *Symphurus*. *a.* postlarval specimen 18—20 mm. *b.* adult specimen 100 mm.

In *Symphurus* there is no essential difference from other flat-fishes in this regard. In the later postlarval or early metamorphosed stages (e. g. 20 mm., text fig. 24 a) these separate ural elements can be clearly distinguished; they are in fact homologous to interspinous elements, such as we find for example at the base of the first haemal, caudal spine. It is customary to call the uppermost ural element the epiural, on the understanding, that it develops above the urostyle. This is not altogether the case, however; this bone develops round the end of the urostyle, replacing the latter more and more as it becomes absorbed; the inner end becomes fused with the lower edge of the second-last neural spine and thus comes to lie above the urostyle in the later stages. In *Symphurus* the urostyle is always short and the epiural thus always lies above the urostyle. Immediately below the epiural we have the first pair of ural bones, here separate and remaining separate at their distal ends throughout life; then comes a similar pair below the middle line, which also

remain separate distally. Proximally, however, they fuse together and with the proximal end of the first pair. Lastly, we have an odd element below corresponding to the epiural above and resting similarly on the posterior edge of the second-last haemal spine. What happens now to produce the diphycercal form can be readily understood. The bases of the fused central pairs gradually take the place of the disappearing urostyle and become attached to the second-last vertebra (in reality the last), the distal ends remaining free and symmetrical above and below. Nevertheless, the fact that the haemal and neural spines of the second-last vertebra grow far back to support the outermost ural elements, means that the "tail" can always be readily distinguished. The arrangement of the caudal rays on the ural elements is as follows. The epiural supports the 2nd and 3rd upper rays in the middle and part of the 1st above and part of the 4th below; the first hypural spine supports the 4th and 5th rays, the second hypural the 5th and 6th rays; here we have the middle line; then the third hypural corresponds the 7th and part of the 8th, the fourth hypural the 8th and 9th; the 5th hypural, which supports to the epiural, also supports 2 rays in the middle, the 10th and 11th, above also part of the 9th and below part of the 12th; lastly, the neural and haemal spines of the second-last vertebra support respectively part of the 1st and part of the 12th rays. It is a characteristic of this group of flat-fishes, that the tail has an even number of rays; as a rule there is an odd number (17 or 19).

A similar transition from the homocercal to the diphycercal form of tail has been noted by Ryder (1884) in the genus or family of *Anguilla*, but I am not aware, that it has hitherto been shown to occur in the life-history of a single species.

The anal fin is also remarkable in its way. In the early postlarval stages of all other flat-fishes, so far as these stages are known, the posterior wall of the abdominal cavity is formed by the large interspinous bone (*Pleuronectes, Rhombus, Arnoglossus* etc.) or by a number of smaller interspinous bones (*Solea*). These can be seen at a very early stage and form the support below of the first rays of the anal. In *Symphurus*, however, these interspinous bones are absent until a late postlarval stage and, as will be mentioned below, the abdominal cavity has no posterior wall in consequence (figs. 41—43). This conspicuous difference from all other flat-fishes, including *Solea*, might indicate that we have here a form which stands nearer to one or other "round fish" than any other flat-fish does.

We may turn now to the abdominal cavity and the organs connected therewith. Firstly, it may be noted, that there is a distinct air-bladder, comparatively small to begin with and lying somewhat posteriorly (fig. 41), later growing larger and taking up more room anteriorly (fig. 43). On metamorphosis the air-bladder completely disappears (fig. 44). In consequence of this large air-bladder and the absence of the supporting interspinous bones posteriorly, the abdominal "sac" containing the alimentary tract, liver, pancreas etc. comes to lie outside the "body". The intestine has a single coil, to the left, the large intestine passing behind (when viewed from the left or future eyed side) the pyloric end of the stomach. The rectum is quite short to begin with and projects but little from the abdominal "sac" (fig. 41), but later it pushes out more posteriorly and horizontally and comes to lie on the right or blind side, along the first 3—4 anal rays and interspinous bones (fig. 44). The liver is small by comparison with what we have found in *Arnoglossus* and *Bothus*; the pancreas, however, is comparatively large. There is no sign of pyloric caecae.

The most remarkable thing about the abdominal "sac" is, however, the peculiar cone-like organ or "appendix" projecting freely from the posterior wall (figs. 41—43). This at first sight has all the appearance of being a parasite, as if, in any case, it did not belong to the abdominal cavity. It is present in all specimens, however, and, as already mentioned, can even be noticed in Emery's imperfect figures of the early so-called "*Trachypterus taenia*". It is, so far as I can determine, a simple, empty sac opening into the main abdominal cavity. At first, I thought it might be a secondary cavity or rather the rudiment of the prolongation of the main cavity, such as we find in the adult Soles, but I have failed to find any

trace of it, either in the metamorphosed or adult specimens. It seems to me, that it must be thrown off on metamorphosis. In *Solea* and other species of *Symphurus*, there is no trace of this organ.

The pigmentation is not unlike, in distribution, what we find in postlarval specimens of the *Arnoglossus* genus. In the early stages there is a postanal bar of black pigment not far from the tail and a row along the base of the anal interspinous region. A dorsal interspinous row is more inconstant, but a few spots are generally present. Just as in *A. Rüppeli* the postanal bar extends out on to the anal fin, only seldom on to the dorsal fin (figs. 41—43). Further, in some specimens, most of the D. and A. rays are dotted at the end, just as in some species of *Solea*. The air-bladder is always well-provided with chromatophores, which also have a rusty, brownish-yellow colour as in some species of *Arnoglossus*. There is also a rich supply of chromatophores on the lower as well as the posterior walls of the abdominal sac and the "appendix" is covered with small pigment spots. A few spots may be present along the lower margin of the gill-cover and the membranous fringe of the pectoral fin may also show a few rows of small dots (figs. 41—43). There is, naturally, some variation in the distribution and amount of pigment, but the three figures of the postlarval specimens may be taken as fairly representative.

Metamorphosis brings with it fundamental changes in this species, as might be expected. The adult has no sign of the elongated dorsal rays, the protruding abdomen and the pectoral fin disappear and the form becomes flat and slender, more or less like a Sole, but with the eyes on the left instead of the right side. Without all the transitional stages before one, it would be hard to believe, that the flat, tongue-like adult could have any connection with the torpedo-shaped, postlarval form.

Fig. 44 represents a specimen 20 mm. long, which has just completed metamorphosis, or is just metamorphosing, fig. 43 a specimen of 18 mm., in which the position of the eye and other structures show, that metamorphosis has just begun, text-fig. 23, lastly, shows a completely metamorphosed specimen of 27 mm. in length. A comparison of these 3 figures will explain the transformation which takes place.

At 18 mm. the torpedo shape is still evident, the first dorsal rays are still long, though relatively reduced in length, the club-shaped pectorals and the air-bladder are still present and the abdominal sac is still outside the "body". The head, with the gill-cover, is however relatively deeper and flatter than in earlier stages and the right eye is asymmetrical, appearing slightly above the left. The integument, especially on the head and fins, has a thickened, papillose[1] appearance and this integument is forming a distinct snout in front of the nasal region, covering the premaxilla and overhanging the lower jaw. An even more conspicuous sign of approaching metamorphosis is the growth forward of the anal fin, which means, as we have seen in *Arnoglossus* and *Bothus*, that the interspinous bones behind the abdominal cavity are now formed and growing forwards below to partially enclose that cavity. At the same time, some extra pigment has appeared along the vertebral column.

There is only a difference of 2 mm. between fig. 44 and fig. 43, but the difference in form and structure is very great, indicating that the intervening stages of metamorphosis must be passed through very rapidly, if not abruptly, just as we found to be the case in *Arnoglossus* and *Bothus*. The air-bladder has disappeared, the pigment which covered it appearing now merely as a line along the lower edge of the abdominal hæmapophyses. The space left is now filled by the abdominal sac, which has been retracted into the "body", and the thick integument has grown over it. It appears, therefore, that the sac which surrounded the abdominal organs in the earlier stages and hung freely from the vertebral haemapophyses and ribs, was the peritoneum. It can still be seen, with the pigment spots on it, lying inside the integument. I have not been able to find any trace of the "appendix", however, and conclude, that it must have been thrown off, when the abdominal sac was withdrawn. The integument is now

[1] The papillose condition may be pathological.

covered with scales at various parts, especially over the lower part of the abdomen and head; each scale bears one or three large spines. These spines can be seen on the ventral edge of the abdomen in the figure (Pl. IV, fig. 44).

The snout is now distinctly formed in front of the head, but the fish is sufficiently transparent to show without difficulty, that it is composed entirely of superficial tissues, the premaxilla, nasal and ethmoid regions occupying very much the same position relative to the lower jaw as before. Above, the snout is supported in its forward position by the framework of bones already mentioned, and it is quite evident, that the migrating eye has come through the integuments under these and above the original frontal bone of the skull. In *Solea*, it will be remembered, the migrating eye moves round in front of the dorsal fin. It is also evident, that this migration of the eye is not yet quite completed, as the bony framework is still pressing on part of the eye-ball, but the gap is quite closed. The long rays of the dorsal fin are now reduced almost to the level of the succeeding rays, but their position relative to the underlying interspinous bones is still the same as in the preceding stages. It may be remarked here also, that in all good drawings of species of *Symphurus* (e. g. those of the American author GILBERT 1905), the first 5 to 7 dorsal rays are represented as further apart than the remaining rays. Hence, it may be concluded, that these anterior rays in all species of *Symphurus* have in the beginning been elongated rays and go through the same change as in the species described here; the separateness of the rays being due, as mentioned above, to their peculiar connection with the interspinous bones. Lastly, the pigment in the specimen figured is very extraordinary; it may be abnormal, but traces of the same pigmentation were present in the earlier specimen and persist in the next, metamorphosed stage. In the centre of the caudal region is a broad, leaf-like expansion, which is composed of innumerable, interlacing lines of pigment arranged about stems or branches, which radiate out between the myomeres from the central, broad tract of pigment along the vertebral column. This tract extends forwards to the head with here and there a few frills of pigment on each side, mostly dorsally; on the blind side of the body the leaf-like expansion is not present, the only pigment being the broad tract over the vertebral column. On both sides there is a darker, narrow line along the middle line of the vertebral column. Perhaps this pigment line has something to do with the lateral line system, but no trace of this can be seen, at this or any later stage.

At 27 mm. (text-fig. 23, p. 130) we have practically the adult form; the specimen happens to be a female and the ovary can be seen to be already of considerable length. The whole fish is now densely covered with minute, ciliated scales, embedded in the thick, almost opaque integument. The peritoneum or abdominal sac of the earlier stages is densely pigmented. Of the median pigment of the earlier stage there only remains the dark, central line (equivalent of the lateral line?) with a slight fringe on the caudal region in the position of the leaf-like expansion of the previous stage. Darker shadings also appear towards the fins and on the head; on the fins are a large number of "bars", each consisting of one or two rows of small dots of pigment. The ventral fin is relatively shorter than in the previous stage. The snout is fully developed and there is a notch in the thick integument covering the lower jaw for the reception of the dependent tip of the snout. The small eyes are now deeply embedded in the thick integument, which is dense and opaque. On staining and clearing, however, the internal structures described above can be clearly seen. As already mentioned, the loose integument surrounding the head is supported by a number of extraneous bony stays, thus 3—5 special, long rods above the head, about 12—15 small, slender, perpendicular rods projecting downwards and outwards from the lower flange of the mandible (dentary), then the 7 long branchiostegal rays and lastly, the opercular and subopercular bones are for the most part transformed into a large number of radiating bony rods, which support the posterior portion of the gill-cover over the pectoral girdle.

Although the continuity of the characters from the earliest to the latest stages and thence to the adults, is sufficiently complete to place the identity of the series of postlarval forms beyond doubt, for the sake of control the vertebrae and fin-rays have been counted in a number of specimens with the following results:

5 adult specimens (65—100 mm. long)...	D + C + A = 87 + 12 + 71 = 170		
	— = 90 + 12 + 70 = 172		
	— = 88 + 12 + 73 = 173;	Vert.	9 + 40
	— = 87 + 12 + 73 = 172;	—	9 + 41
	— = 91 + 12 + 78 = 181;	—	9 + 40
2 metamorphosed specimens	— = 88 + 12 + 75 = 175;	—	9 + 40
	— = 90 + 12 + 77 = 179;	—	9 + 41
8 postlarval specimens.....	— = 85 + 12 + 74 = 171;	—	9 + 40
	— = 84 + 12 + 73 = 169;	—	9 + 39
	— = 88 + 12 + 77 = 177;	—	9 + 39
	— = 87 + 12 + 76 = 175;	—	9 + 39
	— = 89 + 12 + 78 = 179;	—	9 + 41
	— = 88 + 12 + 72 = 172;	—	9 + 40
	— = 86 + 12 + 73 = 171;	—	9 + 40
	— = 87 + 12 + 75 = 174;	—	9 + 40

It will be seen, that the agreement is as good as could be expected; the variation is not any greater than what we have already seen to occur in *Arnoglossus* and *Bothus*. It may be taken as certain, therefore, that all these specimens belong to one and the same species, *Symphurus lactea*[1].

Chart 7. Distribution of *Symphurus lactea* (Bonap.).
× = Known occurrence of adults.
○ = Postlarval specimens taken by the "Thor".

Distribution and spawning period. As shown by the accompanying Chart 7, *Sym. lactea* is distributed in the Mediterranean from the Straits of Gibraltar to the Adriatic and probably further east. The locality and date of capture of the postlarval specimens can be seen from the following summary; no postlarval specimens have been taken in the Atlantic, though the adult has been taken in the Bay of Biscay (Vaillant 1888) and near the Azores (Collett 1896).

[1] Bonaparte gives D + C + A = 162, Canestrini 160—178.

Locality	Straits of Messina	Balearic Sea	Catalonian Sea	Balearic and Alboran Seas	Ionian Sea	Tyrrhenian Sea
Month of capture	August			September	December	January
Number of specimens	13	2	3	16	1	1
Size in mm.	5·5—13	12, 17	6·5—9·5	6—18	20	27
Depth at Station m.	100—1140	ca. 2860	1000—2000	200—>2000	>1200	90
Approx. depth of capt. in m.	11 at 0 2 - 400	0	0	14 at 0 2 - 200	ca. 40	90

It appears from this summary, that the spawning period of *Symphurus lactea* lies in the summer months. From the specimens of 12—17 mm. in length taken in August, we may conclude that the species spawns about May and, from the specimens of 6 mm. in length taken in September, continues spawning until July or August. The metamorphosed specimens taken in December and January indicate, either that the spawning time is continued later in the autumn or that the postlarval life may be very prolonged.

Regarding this species I may mention, that I took what I believed to be the pelagic eggs at Banyuls in April to June. The adults were found to be nearly ripe in April. The eggs and larva are quite characteristic. The egg measures only ·6 to ·63 mm. and has no oil-globule. The larva is only 1·45—1·75 mm. in length when hatched and possesses already a considerable amount of pigment, in the form of small black chromatophores or (pathologically) dots over the head and yolk-sac, along the vertebral column and round the margin of the body; further, there is a distinct postanal bar of separate, scattered chromatophores (not grouped in a mass as in *Onos, Arnoglossus* etc.) halfway along the caudal region and extending out on to the marginal fin; also a group on the dorsal embryonic fin above the pectoral region. Lastly, the yolk-sac is small and the anus opens some distance behind it. There is naturally no sign as yet of the future, so characteristic, postlarval structures.

SYMPHURUS LIGULATA (Cocco).

? *Symphurus nigrescens* Rafinesque 1810.

Postlarval stages:

Bibronia ligulata Cocco 1844; Facciolà 1885.

Peloria Rüppeli Emery 1883.

Ammopleurops sp. Lo Bianco 1908 b.

D + C + A = 106—109 + 14 + 95—96 = ca. 217. V. 0/4. Vert. 9 + 48—49 = 57—58.

So far as I am aware, the adult form of this species has never been described[1]. As Bonaparte did not think, that Rafinesque's species *Symphurus nigrescens* could be the same as *Sym. lactea*, it is possible, that Rafinesque's diagnosis was intended for the present species, but it is impossible to decide this question. The reasons for regarding this species as distinct from *Sym. lactea* or *picta* have been stated under the preceding species.

[1] A new species of *Symphurus* was taken by the Valdivia on the east coast of Africa (0° 27′ 4″ S., 42° 47′ 3″ E.) which may perhaps be the parent form of *Sym. ligulata* (Cocco). According to Brauer (1906) this new species, *Sym. fuscus*, has the fin-ray formula D + C + A = 105—106 + 14 + 90—91. If this should be the same species as *Sym. ligulata*, its distribution is extensive, unless we imagine, that it extends through the Suez Canal to the Red Sea, which seems improbable. Until further information is forthcoming, it seems best to regard *Sym. ligulata* as a Mediterranean and Atlantic species, the parent form of which has not yet been described.

This species has not been taken by the "Thor", but in the supplementary collections made by Danish steamers there are 2 specimens, which undoubtedly belong here. The first and smaller specimen was taken in the Mediterranean itself, the second and larger specimen in the Atlantic a little to the south of the Canary Isles. Though widely separated in stage of development these 2 specimens agree exactly in essential specific characters and also with the description given by EMERY of his so-called "*Peloria Rüppeli*".

The smaller specimen of this species in my material was taken in August 1911 by the s. s. "Pangan" at 35° 50′ N., 21° 30′ E. near the surface, thus in the Eastern Mediterranean in the Ionian Sea. It is 10·5 mm. in length and, as the figure shows (fig. 45), can at once be recognised as distinct from the postlarval form of *Sym. lactea*. The ventral fin is greatly elongated, agreeing with Cocco's description of *Bibronia ligulata:* "Le ventrali son jugulari co' raggi posteriori molto allungati".

The remarkable, sac-like appendix to the abdominal cavity, which characterizes the postlarval stages of *Sym. lactea*, is missing here. The peduncle of the pectoral fin is broad, not so elongated as in the former species and the air-bladder is small at this stage.

In addition to these obvious differences, the number of fin-rays is very much larger than in *Sym. lactea*; 105 can be counted in D, but the last few rays are not yet differentiated, the caudal fin has only 8—10 distnct rays as yet; A has ca. 90. The total number is thus well over 200, whereas the range in *Sym. lactea* was found to be (160) 169—181. The number of vertebrae is here 57—58; in *Sym. lactea* it was 48—50. The pigmentation is also different; there is no bar postanally, but simply a dorsal and anal row along the bases of the interspinous regions with a few spots on the head and membranous margin of the pectoral fin.

The general characteristics of the genus can be seen very clearly from the figure. The first five dorsal rays are elongated, the 3rd and 4th the longest (the 2nd was broken); these are all articulated distally. The caudal fin and hypural bones have the same structure as in *Sym. lactea* and also the anal fin, which begins far forward under the pectoral. The ventral fin is narrow and elongated, the third ray the longest, and thus has a strong attachment by ligament to the base of the clavicles. The pubic cartilaginous bar extends posteriorly nearly to the end of the abdominal sac. As in the early stages of *Sym. lactea* the lower part of the head (opercular bones, gills etc.) is enveloped in a large, loose, integumentary sac, which posteriorly reaches well behind the clavicles; it is supported by 7 branchiostegal rays. The abdominal sac contains the long, single coil of the intestine, the rectum and anus lying higher up on the right side than in *Sym. lactea*, also the liver in 2 or 3 lobes along the ventral branch of the intestine and partly surrounding it, the pancreas between the coil and posteriorly a flattened organ which possibly represents the spleen.

My second, larger specimen (fig. 46) was taken by the s. s. "Florida" on September 20th 1912 at 24° 49′ N., 19° 26′ W., thus a little to the south of the Canaries and not far from the coast of Africa. It is 32 mm. in length. Though widely separated from the first in degree of development, there can be little doubt of its belonging to the same species. Thus, there is a conspicuous lack of pigment, the row of spots along the base of the interspinous regions, which was fairly well-marked in the earliest stage, being here barely visible. In this larger specimen a few dots of pigment are present on the front dorsal rays. Otherwise there is no pigment; for example, there is no pigment bar across the body as in *Sym. lactea*. Again, there is no appendix to the abdominal sac. The fin-ray formula is $D + C + A = 109 + 14 + 95 = 218$; the earlier specimen had well over 200, but the rays were not all developed. The base of the ventral fin, again, is a heavy structure just as in the first specimen, evidently correlated with the great development of the ventral rays. These are relatively shorter here and so also are the elongated dorsal rays, obviously a sign of approaching metamorphosis. Further, the pectoral fins have the same broad appearance, whereas in *Sym. lactea* they were club-shaped (cf. 42, 43). Lastly, the air-bladder, if present, must be very small.

A remarkable specific difference from *Sym. lactea* is, that the caudal fin contains 14 rays, not 12 as in *Sym. lactea.* As will be noted below, EMERY also found 14 in his "*Peloria*".

This larger specimen is apparently about to metamorphose. From the left side, the right eye can be seen above the left and, what is more remarkable, it almost looks as if the whole of the upper structures above the eye (muscular tissue and interspinous stays) become loosened from the snout to let the eye pass through, just as in *Arnoglossus.* This effect, however, may be due to injury, as in *Sym. lactea* and another species from American waters to be described later, the migrating sinks through the tissues without the upper structures becoming detached from the snout.

Whilst the elongated ventral and the absence of the abdominal appendix identify these specimens with COCCO's *Bibronia ligulata* and distinguish it from *Sym. lactea,* it may be said, that the fin-ray formula does not agree with COCCO's statement, repeated later by FACCIOLÀ (1885). COCCO gives D. ca. 90, A. ca. 80, numbers which agree better with *Sym. lactea.* This makes me inclined to think, that both species were represented in COCCO's material; his description applies, so to speak, to a combination of both species, but to neither separately.

On the other hand, EMERY's description of postlarval specimens of his "*Peloria Rüppeli*" (not "*Peloria Rüppeli*" of COCCO, a mistake pointed out by RAFFAELE in 1888) agrees precisely with the present specimens. EMERY remarked also, that the fin-ray formula of his specimens (4/102 + 14 + 96 = 216) did not agree with that of *Sym. lactea.* He states also, that the species metamorphoses about 31 mm. As shown above, *Sym. lactea* metorphoses about 20 mm. and my larger specimen of 32 mm. is just beginning metamorphosis.

There can thus be no doubt as to the separateness of these two species, *Sym. lactea* and *Sym. ligulata.* There are only two specimens of the latter in my material, but as COCCO and EMERY had several specimens, taken both at Messina and at Naples, and as LO BIANCO only mentions this species ("*Ammopleurops* sp.") in his Naples collections, it is possibly not so very rare in the Mediterranean. The fact, that it metamorphoses at a greater length and has a higher number of vertebrae and fin-rays than *Sym. lactea,* indicates, that it frequents deeper water than the latter species.

Appendix

In addition to the European and Atlantic species of flat-fish dealt with in the foregoing, a number of other species have been taken in the Atlantic during the supplementary collections of recent years. These are mostly species from the American side of the Atlantic. Unfortunately, not only is the available classification of the American flat-fishes artificial and imperfect, but the work of identifying the postlarval stages has not yet begun. Hence, to determine the parentage of a few specimens taken at large over deep water is more or less speculation.

ARNOGLOSSUS sp.

A single, postlarval specimen of an *Arnoglossus* species distinct from any of the forms described in the text was taken by the s. s. Texas on May 3rd 1912 at 15°30′ N., 23°52′ W. As the accompanying outline figure shows, this specimen has all the characteristic *Arnoglossus* features, elongated form, a long tentacle, here unusually long (8 mm.), a distinct gap between the base of the tentacle and snout indicating an intermediate developmental stage, left ventral in front of the base of the clavicles, long cartilaginous

pubic bar extending along the ventral margin of the abdomen, pigmented air-bladder and lastly, a complete system of spines all round the interspinous regions and tail from the tentacle to the anus and on to the base of the ventrals.

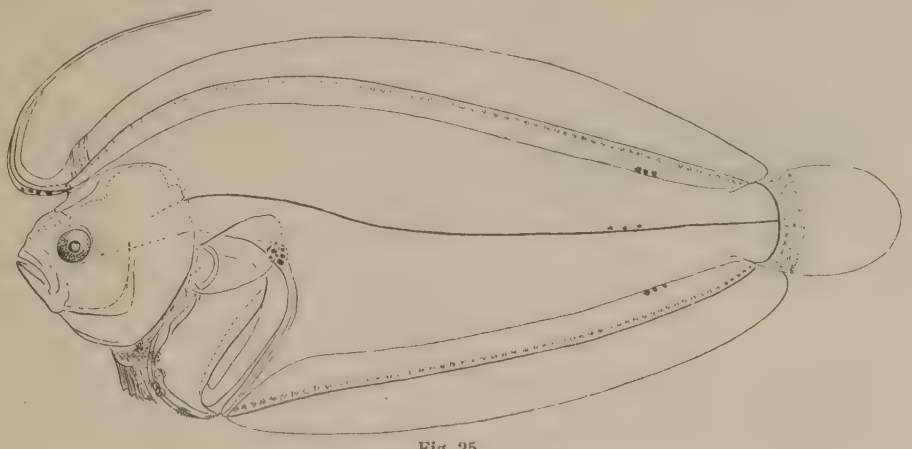


Fig. 25.

Whilst the genus is thus easily recognised, the species is one I am not acquainted with. The specimen is 23 mm. long and obviously some distance from metamorphosis; further it has but little pigment; a few spots to mark the postanal bar near the tail, also a few on the air-bladder and no others. Its fin-ray formula is D. 96, A. 75, the vertebrae number 10 + 31 = 41. It is thus similar to the larger forms of *Arnoglossus laterna* (forma *Biscayensis*), but there are very distinct differences from the postlarval stages of that species. In the first place, the liver is so large, that only the descending branch of the intestine can be seen from the left side and in the second place, spines are present ventrally along the cartilaginous pubic bar. This latter character assimilates the specimen to *A. Thori* or *A. imperialis*, but the pigmentation and other characters (number of fin-rays and vertebrae) are against these species.

The distribution of the spines is represented in the figure. With regard to those ventrally along the cartilaginous bar, there is this difference from *A. Thori* and *A. imperialis*, that they are not grouped in small, definite plates, but rather spread out indefinitely. In fact, the nature of the spines resembles that in *A. laterna* (see pp. 41—44) but the plate-like base is more definite than in that species. It is thus an intermediate form between *A. laterna* and *A. imperialis*, with more affinities to the former.

From the locality where it was taken, S. E. of the Cape de Verde Islands, we may conclude, that it belongs to some species of the African fauna, to be found probably on the Cape de Verde Islands. It has apparently nothing to do with the Mediterranean or European fauna.

BOTHO-RHOMBINAE

A postlarval specimen belonging to a subfamily of flat-fishes not yet recognised in any classification was taken in the western Atlantic by the "Ingolf" as 22°16′ N., 63°05′ W. on March 3rd 1911. The locality lies about 300 miles N. E. of Porto Rico and just within the borders of the Sargasso Sea. The specimen is 46 mm. long and still symmetrical, though apparently not very far from metamorphosing. From various characters, eyes, ventral fins etc., it can be seen, that it belongs to a sinistral flat-fish. The accompanying text-figure 26, which is reproduced from a photograph of a stained and mounted specimen, gives a good impression of its characteristics. The liver and fins are slightly damaged and the pigmentation has been lost on photographing; otherwise the structural details can be clearly seen. As regards pigment, it may just be mentioned, that there is a thin, continuous, black streak along the base of the dorsal and anal interspinous regions and also a similar but fainter streak along the dorsal margin of the vertebral column; there is no pigment anywhere else.

At first glance, the specimen strongly suggests affinity to *Arnoglossus*, in the elongated form, the long "tentacle" with its base separated from the snout, the ventral fin in front of the base of the clavicles and the long cartilaginous pubic bar reaching back to near the anus; further, the remnant of an air-bladder can be detected and the posterior abdominal vertebrae have closed hæmapophyses. But there are other wide differences from *Arnoglossus*. In the first place, there are no spines on the head or body; secondly, instead of 10 abdominal vertebrae there are 16, the first 4 of which as in *Arnoglossus* bear open parapophyses, the last 12 hæmapophyses without ribs so far as I can find (thus, as in *Solea*); thirdly, not only is the left ventral fin developed forwards in front of the base of the clavicles, the right is so also. It can be seen fairly clearly in the figure, that the left ventral begins well in front of the clavicles, even though it has not yet reached its final position, and that the right ventral begins just one ray behind the left and still in front of the clavicles. This latter character brings the specimen into affinity with the subfamily *Rhombinae* (turbot subfamily), which has both ventrals elongate and extending forward to the urohyal. In the *Rhombinae*, however, the parapophyses of the abdominal vertebrae are open and the postlarval specimens have no cartilaginous pubic bar.

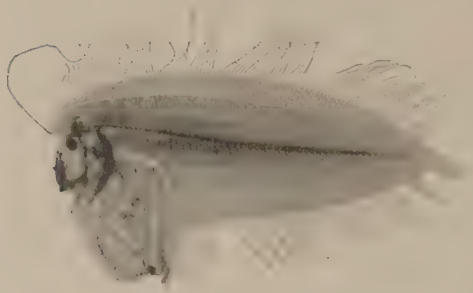


Fig. 26.

This single specimen, therefore, cannot be placed either in the *Bothinae* or in the *Rhombinae*. It shows little affinity, in fact, with the known Atlantic forms (so far as they have been satisfactorily described); its affinities lie rather with the Indo-Pacific *Samaris*, also of uncertain position, which has closed haemapophyses and symmetrical, extended ventrals. *Samaris*, however, is a dextral form, whereas the present specimen is distinctly sinistral. The olfactory organ is unfortunately not yet developed, so that it is impossible to say, whether the specimen is pleuronectid or rhomboid in this regard. Altogether, so far as the characters of the genus or species can be determined, they lie between *Rhombus* and *Arnoglossus*, and to mark this position, I refer the specimen provisionally to the hybrid subfamily *Botho-rhombinae*.

The fin-ray formula is D. 120, A. 88, C. 17, V. 6/6; the vertebrae number 16 + 40 = 54. But there is a peculiarity about the anal fin. As in *Arnoglossus* and *Rhombus* there is a large interhæmal spine to the first caudal vertebra and this spine is continued outwards by one or two cartilaginous prolongations, altogether nearly as long as itself (just as in *Rhombus*, as I have figured earlier, 1900 b) and along this prolongation there are as yet no anal rays nor any appearance, that there will be any. If such develop later, then the total number of anal rays will be about 10 more or in all ca. 100.

With exception of *Hippoglossus* no species of flat-fish yet known possesses such a high number of abdominal vertebrae and we have to descend among the soles to find any with such a high number of caudal vertebrae.

The affinities of this large, pelagic form are thus a mystery for the time being. Goode (1880) and Goode and Bean (1886) have described 2 species of deep-water species from the Gulf Stream and Caribbean Sea, which may well be related to our specimen. The first species, called *Monolene sessilicauda*, has D. 98 to 103, A. 79 to 84, Vert. 43, the second, called *Monolene atrimana*, D. 124, A. 100, number of vertebrae not stated. In these the caudal fin is subsessile as in our specimen. It is quite possible, therefore, that the present specimen belongs to the genus *Monolene*, perhaps even to *M. atrimana*, but unfortunately we know nothing as yet of the important, generic and subfamily characters of *Monolene*.

PARALICHTHINAE

This subfamily is represented by 2 genera and 3 species in the supplementary collections made by Danish vessels in 1911—12 in the western Atlantic. The subfamily characters are seen in the closed hæmapophyses of the posterior, abdominal vertebrae, the position of the symmetrical or asymmetrical ventrals close behind the base of the clavicles, symmetrical or subsymmetrical mouth and sinistral eyes. Further, in metamorphosing specimens the nasal organ of the blind side can be seen to be pushed up on to the ridge of the head and in one specimen the olfactory laminæ were found to radiate from a median rachis. As pointed out in an earlier paper (1900 b) these are the characters of a special subfamily constituted by me (*Hippoglosso-rhombinae* = *Paralichthinae* Tate Regan) including the European species *Citharus linguatula* L. and a large number of American species.

It appears from the 3 species represented in the material, that metamorphosis takes place in this subfamily somewhat as in the *Rhombinae* (turbot subfamily). The migrating eye moves to its final position in front of the dorsal fin and not as in *Bothus* and *Arnoglossus*.

Whilst the subfamily to which the postlarval specimens described below is thus certain, the genera and species are not so evident. As a matter of fact, the generic characters are mostly based on the adults, e. g. nature of the scales, course of the lateral line etc., and we thus have but little to go upon in the identification of postlarval specimens. In one of the species, however, the anterior dorsal rays are elongated and the left ventral is much longer than the right. Assuming that these characters persist in the adult — and this will certainly be the case with the ventrals fins — then this species belongs to the genus *Ancylopsetta* Gill (= *Notosema* Goode and Bean, 1884). Other characters are also in good agreement with this determination, as will be shown below.

The other 2 species show affinities to the *Paralichthys* group of the *Paralichthinae*, the ventral fins being symmetrical, but the dorsal and anal fins end close to the tail, which excludes *Paralichthys*. As the mouth is fairly small, further, I feel obliged provisionally to refer these species to the *Citharichthys* group, though admittedly only on the grounds, that this is their nearest "affinity".

Ancylopsetta sp. The appearance of the postlarval specimens referred here can be gathered from the accompanying text-figure. The material contains in all 16 specimens of this species, all of the same size, 6—7 mm., and all taken in October 1911 and May 1912 within a certain restricted region, from 38° to 42° N. and 57° to 69° W., thus off the middle States of North America and within the influence of the Gulf Stream. In spite of their small size, development is far advanced, the vertical fins and vertebrae being fully formed. We may believe, therefore, that we have to deal with a coastal and not a deep-water species. The eye is large and the mouth of moderate size.

Fig. 27.

Characteristic features are: the elongated 6—7 dorsal rays anteriorly, elongated left ventral, an air-bladder under the anterior abdominal vertebrae, spiny armature on the head and lastly, the pigment. The elongated dorsal rays remind one of the elongated rays of the adult in *Ancylopsetta* as also the elongated left ventral. This is at least twice as long as the right ventral. The anterior position of the air-bladder is also characteristic and no less the spiny armature on the head. On the sphenotic region on each side of the dorsal fin, there is a large and stout spine projecting outwards, backwards and upwards; further, the posterior edge of the preoperculum is transformed into a strong, antler-like structure with 4—5 short spines and 1 long tine, projecting backwards, outwards and downwards and with a secondary spine on its upper edge. The distribution of the pigment can be seen from the figure and it

only remains to add, that the chromatophores at the base of the sphenotic spine have a bronze or brownish tinge.

In 3 specimens I have found the following number of fin-rays and vertebrae: D. 80—85, A. 63—70, Vert. (9) 10 + 25 = (34) 35.

The genus *Ancylopsetta* is said (JORDAN and Goss) to differ from *Paralichthys* in the subsessile caudal fin, in the prolongation of the anterior dorsal fin rays and in the prolonged left ventral fin. The determination of the genus thus appears to be certain. JORDAN and Goss, however, only mention 2 species belonging to this genus, *Ancyl. quadrocellata* Gill and *Ancyl. dilecta* (Goode and Bean). The fin-ray formula is said to be the same in both (D. 69—70, A. 55—56) and for the former the number of vertebrae is given as 9 + 26 = 35. So far as the number of vertebrae is concerned, our specimens agree with these species, but there is a wide difference in the fin-ray formula. If the statements of the American authors are quite accurate, and as already shown the number of fin-rays is not their strong point, the discrepancy between number of vertebrae and fin-ray formula would suggest that my specimens belong to a totally different genus. As the structural characters are so obviously those of the genus *Ancylopsetta*, however, I think it right to leave them there provisionally.

? *Citharichthys* sp. A. The form and appearance of the single postlarval specimen referred here can be seen from the accompanying text-figure 28. Its fin-ray formula is D. 95, A. 70; number of vertebrae 11 + 30 = 41. The specimen is in process of metamorphosis at a length of 10 mm., the right eye being apparent on the edge of the ridge when viewed from the left side. The ventrals are quite small, lying symmetrically a little distance behind the base of the clavicles. In each there is apparently only 4 rays and there is no cartilaginous bar running back ventrally from the pubic bones. At this stage there is no visible sign of an air-bladder as such, though it may have been present at an earlier stage. The mouth is only moderately large, judging by what we find in *Hippoglossus* and *Rhombus*. The pigmentation is characteristic, as can be seen from the figure. There are no spines anywhere. The single specimen was taken by the s. s. Pennsylvania at 37° 32′ N., 70° 43′ W., thus about 200 miles east of the coast of New Jersey, on March 3rd 1912.

Fig. 28.

? *Citharichthys* sp. B. The second species is represented by 7 specimens of from 7 to 14 mm. in length. The generic resemblance to sp. A. can be seen from the accompanying text-figure 29, which represents a specimen 12 mm. long. The form and general appearance are the same; there is even a similar distribution of pigment, but sp. A. has more of this, especially on the dorsal and anal fins. In this form (sp. B.) there is a distinct air-bladder. As in sp. A. there is no trace of spines and here also the ventral fins only have 4 rays apparently.

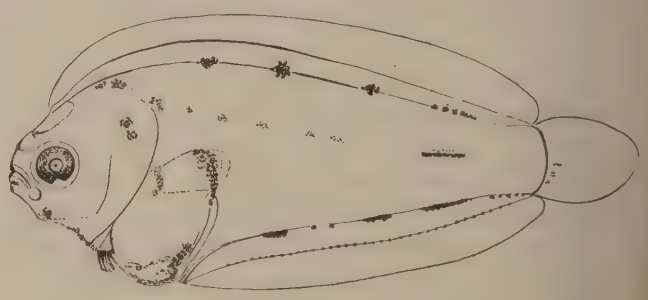


Fig. 29.

Apart from the pigment and air-bladder, there are certain, well-marked specific differences from sp. A. In the first place, even the largest specimen of 14 mm. has not yet begun metamorphosis and in the second place, sp. B. has a smaller number of fin-rays and vertebrae; in 5 specimens I find

D. 77—83, A. 60—66, Vert. (10) 11 + 25—27 = 36—38. — These 7 specimens were taken by the s. s. Pennsylvania on May 6th 1912 at 42° 12 N., 62° 15′ W., thus about 300 miles east of Long Island.

The generic identity of these two species is very evident in the subsessile caudal, position of the ventrals, absence of spines etc. Now the only genus, so far as I know, which contains 2 species corresponding to the above in fin-ray formula and number of vertebrae is *Paralichthys*, but, as already mentioned, this genus seems quite excluded by reason of the subsessile caudal fin and until more complete series have been obtained, it seems better to place them in the *Citharichthys* group.

? SYMPHURUS PUSILLA (Goode and Bean).

Aphoristia pusilla Goode and Bean 1885.

Symphurus pusillus Jordan and Goss 1889; Jordan and Evermann 1898 (1900).

D + C + A = 76 + 10 + 60 = 146; V. 0/4; Vert. 9 + 35 = 44.

The specimen to be described below comes nearest to the "*Aphoristia pusilla*" described by Goode and Bean from the Gulf Stream. The fin-ray formula is given by them as 78—85 + 70—72 = 142—157. Jordan and Goss are inclined to consider this "*pusilla*" as merely a variety of their *Sym. plagiusa* (fin-ray formula 86—95 + 75—80 = 161—175), but as these authors have not had a very high appreciation of the number of fin-rays as a good specific character (see also above under *Bothus atlanticus*, p. 105), it is permissible to regard *pusilla* as a distinct species, at least provisionally. This is also done by Jordan and Evermann (1900). The fin-ray formula of the present specimen (146) certainly cannot be made to fit in with that of *Sym. plagiusa* (161—175), whereas it may very reasonably be taken as agreeing with that of *Sym. pusilla*. In any case, it is better to refer this specimen with a query to a known species than to found a new species on a postlarval specimen.

This specimen was taken by the "Ingolf" near the surface at 18° 45′ N., 62° 20′ W., thus not far from the West Indian Islands. Goode and Bean obtained their specimens at 40° N., but Jordan and Goss refer to possible specimens of *pusilla* from Beaufort and Florida Keys — thus near the coasts. Judging from the low number of vertebrae and fin-rays as well as from the fact, that it metamorphoses at a small size, this species belongs to the littoral or coastal zone far more than the other species of *Symphurus* referred to above.

The specimen is only 14 mm. long but already metamorphosing. In the latter respect it thus fills a gap wanting in the series of *Sym. lactea* and enables us to form a complete picture of the remarkable changes which occur during the metamorphoses of this genus.

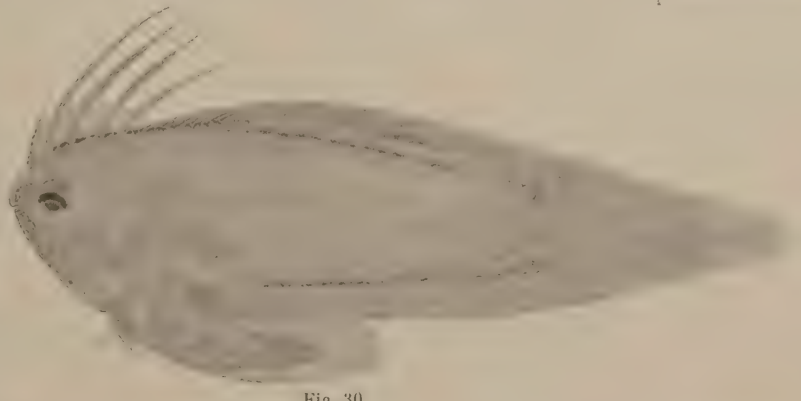


Fig. 30.

In general characters the specimen is intermediate between the Mediterranean species. The rays of the ventral fin are short as in *Sym. lactea*, the posterior appendix to the abdominal cavity is wanting as in *Sym. ligulata*. The 2nd and 3rd are the longest of the elongated dorsal rays. A noteworthy fact here is, that the caudal fin only contains 10 rays, instead of the 12 present in *Sym. lactea* and 14 in *Sym. ligulata*. Thus, the number of rays in the caudal fin appears to be a specific character, which may be of use in grouping together the large number of species of *Symphurus*.

The ventral fin is quite short and thus also its attachment to the clavicles; the cartilaginous pubic bar extends posteriorly in the abdominal sac to the end of the liver. The pectoral is club-shaped as in *Sym. lactea.* The pigment is also somewhat as in the latter species, there being distinct traces of a cross-bar near the tail; along the interspinous regions it is more in the form of dashes than of spots; there is also a line of pigment dorsally at the base of the first 12—15 dorsal fin-rays. On the right (or future blind) side there is a distinct, median line of pigment along the vertebral column to near the tail, which is absent on the left side. Further, a few dull spots can be noticed along the lower jaw and gill-cover and on the vanishing air-bladder on the eyed side. The abdominal sac is longer and narrower than in *Sym. ligulata,* extending almost halfway along the body of the fish. The arrangement of the intestine, liver etc. is as in the two previous species.

The most interesting feature is, however, that the specimen has just begun metamorphosis. This can be seen from the shape of the head, well-developed snout and formation of the bulla on the jaws of the future blind side, as well as from the form of the body, reduction of the air-bladder and increasing enclosure of the space posterior to the clavicles and ventral to the abdominal vertebrae, but most of all from the position of the eye of the right side. As already explained, the head in these postlarval forms of *Symphurus* is imbedded in a thick integument and the right eyeball has begun to retreat from its integumentary "orbit" preparatory to passing through to the other side in the frontal region of the skull, between the overhanging dorsal processes and the snout. It thus looks as it the thick integument surrounding the head and jaws in *Symphurus* was really an extraneous covering, beneath and through which the migration of the eye takes place very much as in *Solea.* An interesting observation by Garman (1899) would indicate also, that the migrating eye does not always succeed in reaching the other side. In his *Sym. atramentatus* he records, that "the right eye of one specimen has failed to come through the skin". A later stage, when the eye has completed the passage through the tissues, is shown in fig. 44 Pl. IV under *Symphurus lactea.* It may be recalled here, however, that in *Sym. ligulata* the migration of the eye seems to take place in a different manner, namely, by the separation of the overlying structures from the snout, somewhat as in *Arnoglossus* (see above p. 140).

30. V. 1913.

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Description of figures.

(The measurements are of specimens in formaline.)

Plate I.

Fig. 1. *Arnoglossus Grohmanni* (Bonap. non auct.); 5 mm.; St. 171, 10—VIII—10.
- 2. do. 6·5 — ; — —
- 3. do. 9 — ; — — D. ca. 73, A. ca. 50, Vert. 10 + 24.
- 4. do. 12 — ; beginning metamorphosis. St. 172, 11—VIII—10.
- 5. *Arnoglossus Thori* nov. nom.; 6 mm.; postanal pigment bar at 18—21 caudal vertebrae; spined plates ventral to liver. St. 122, 2—VII—10.
- 6. do. 8·5 — ; St. 104, 24—VI—10.
- 7. do. 10·5 — ; — —
- 8. do. 12·5 — ; St. 143, 23—VII—10.
- 9. do. 21 — ; metamorphosing. St. 143, 23—VII—10.
- 10. do. 22·5 — ; metamorphosis just completed, lateral line forming. D. 88, A. 67, Vert. 10 + 28. St. 136, 19—VII—10.

In figs. 6–9 the spots along distal margins of D. and A. interspinous regions, on the caudal and ventral fins and on liver and gut, show the distribution of the spined plates (see pp. 41—44 in text).

- 11. *Arnoglossus imperialis* (Raf.); 29·5 mm.; 13—IX—06 (from C. G. Joh. Petersen (fig. 28) 1909).
- 12. *Arnoglossus Rüppeli* (Cocco); 47 mm.; St. 184, 16—VIII—10.

Plate II.

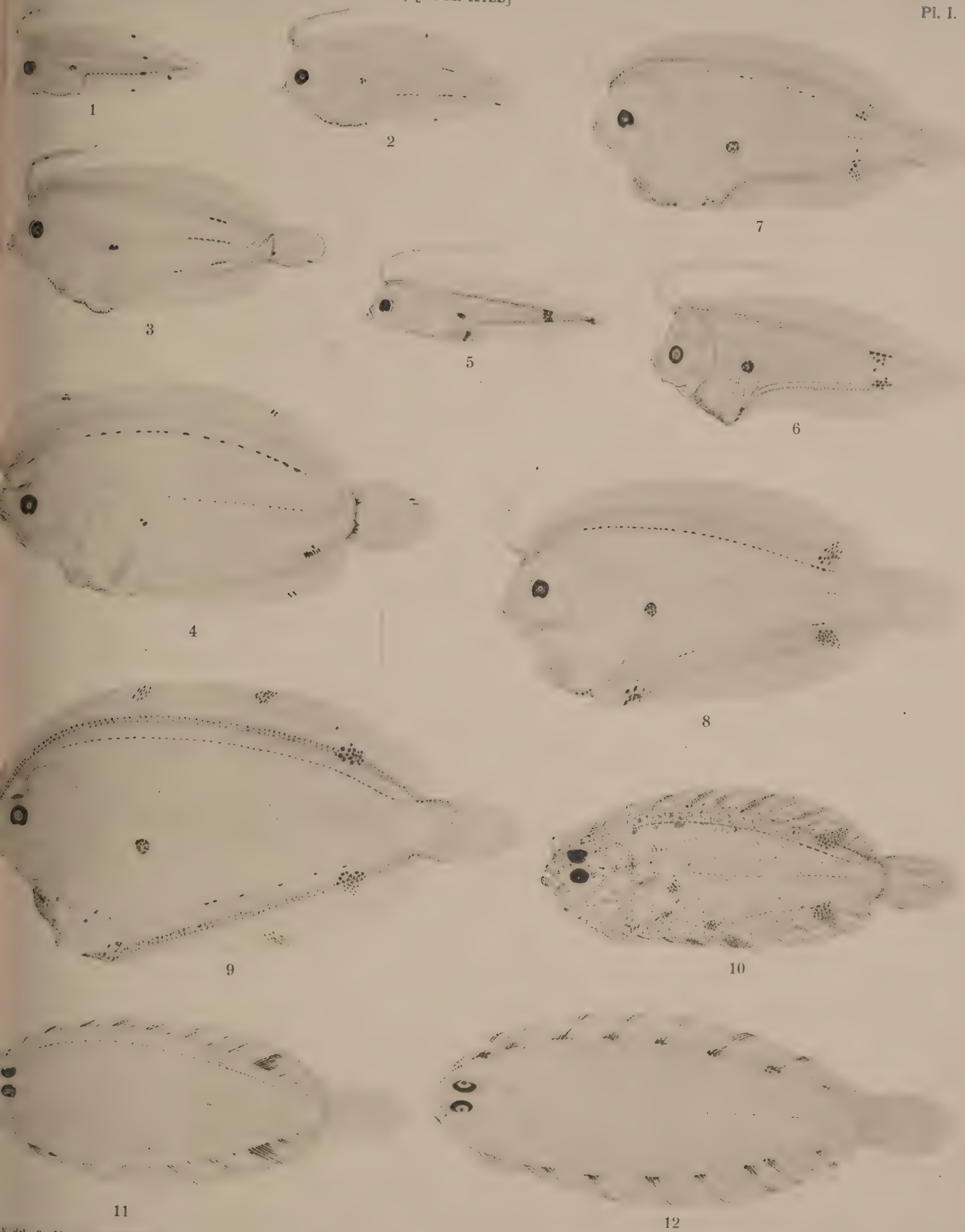
Fig. 13. *Arnoglossus laterna* Will. form A; 6·3 mm.; St. 122, 2—VII—10.
- 14. do. do. 8·5 — ; St. 126, 10—VII—10.
- 15. do. do. 10·3 — ; — —
- 16. do. do. 16 — ; St. 124, 3—VII—10. The spots round the margins show the distribution of the spines.
- 17. do. do. 21 — ; St. 209, 29—VIII—10.
- 18. do. do. 22 — ; metamorphosed; comp. figs. 10, 11, 12. D. 91, A. 69, Vert. 10 + 29; St. 213, 31—VIII—10.
- 19. do. form B; 8·5 mm.; St. 85, 17—VI—10.
- 20. do. do. 12·5 — ; — —
- 21. do. do. 24 — ; — — D. 94, A. 70, Vert. 10 + 30.
- 22. *Arnoglossus imperialis* (Raf.); 6·5 mm.; postanal bar at 22—25 caudal vertebrae; spined plates on ventral line of abdomen; St. 47, 10—II—09.
- 23. do. 10 — ; St. 115, 29—IV—10.
- 24. do. 11 — ; St. 225, 6—IX—10.

Plate III.

Fig. 25. *Arnoglossus imperialis* (Raf.); 18 mm.; St. 10, 15—XII—08. The spots round the margins show distribution of the spined plates (see pp. 41—44 in text).
- 26. do. 29·5 — ; St. 30, 21—I—09. D. 103, A. 80, Vert. 10 + 33.
- 27. *Arnoglossus Rüppeli* (Cocco) 7 — ; St. 193, 21—VIII—10.
- 28. do. 9 — ; St. 224, 5—IX—10.
- 29. do. 12 — ; from a stained and mounted specimen, showing distribution of spines. St. 133, 14—VII—10.
- 30. do. 16 — ; St. 115, 29—VI—10.
- 31. do. 28 — ; showing distribution of single spines on body and of spined plates on margins etc. D. 114, A. 90, Vert. 10 + 34. St. 199, 25—VIII—10.
- 32. *Arnoglossus Thori* nov. nom. Right side of head of specimen 21 mm. long.
- 33. do. Right side of head of specimen 26·5 mm. long; 2nd D. ray still short.
- 34. *Arnoglossus Rüppeli* (Cocco). Right side of head of metamorphosed specimen 41 mm. long.

Plate IV.

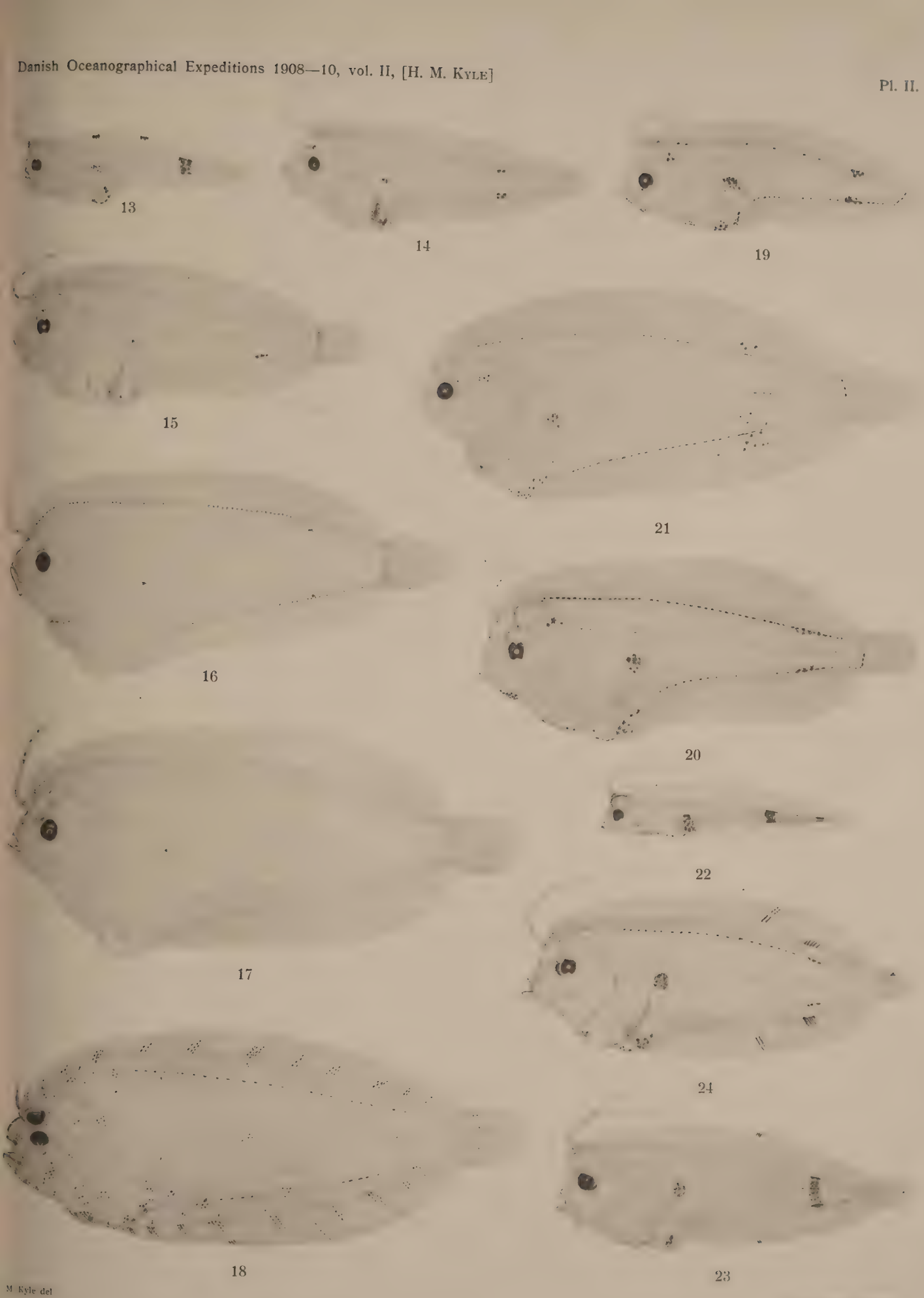
Fig. 35. ?*Solea capellonis* Steind; 9 — ; St. 107, 25—VI—10.
- 36. *S. variegata* (Don); 7 — ; St. 183, 16—VIII—10.
- 37. *S. lutea* (Risso); 6·2 — ; St. 104, 24—VI—10.
- 38. ?*S. Kleini* (Risso); 7 — ; St. 93, 22—VI—10.
- 39. ?*S. lascaris* (Risso); 8 — ; St. 107, 25—VI—10.
- 40. ?*S. nasuta* (Pall.); 5 — ; St. 104, 24—VI—10.
- 41. *Symphurus lactea* (Bonap.); 6 — ; St. 192, 20—VIII—10.
- 42. do. 10 — ; St. 193, 21—VIII—10.
- 43. do. 18 — ; St. 223, 5—IX—10.
- 44. do. 20 — ; St. 13, 19—XII—08.
- 45. *Symphurus ligulata* (Cocco); 10·5 — ; s. s. Pangan, 35° 50′ N., 21° 30′ E.; 26—VIII—11.
- 46. do. 32 — ; s. s. Florida, 24° 49′ N., 19° 26′ W.; 20—IX—12.



K. del., fig. 11 H. V. Westergaard.

Pacht & Crone phototyp.

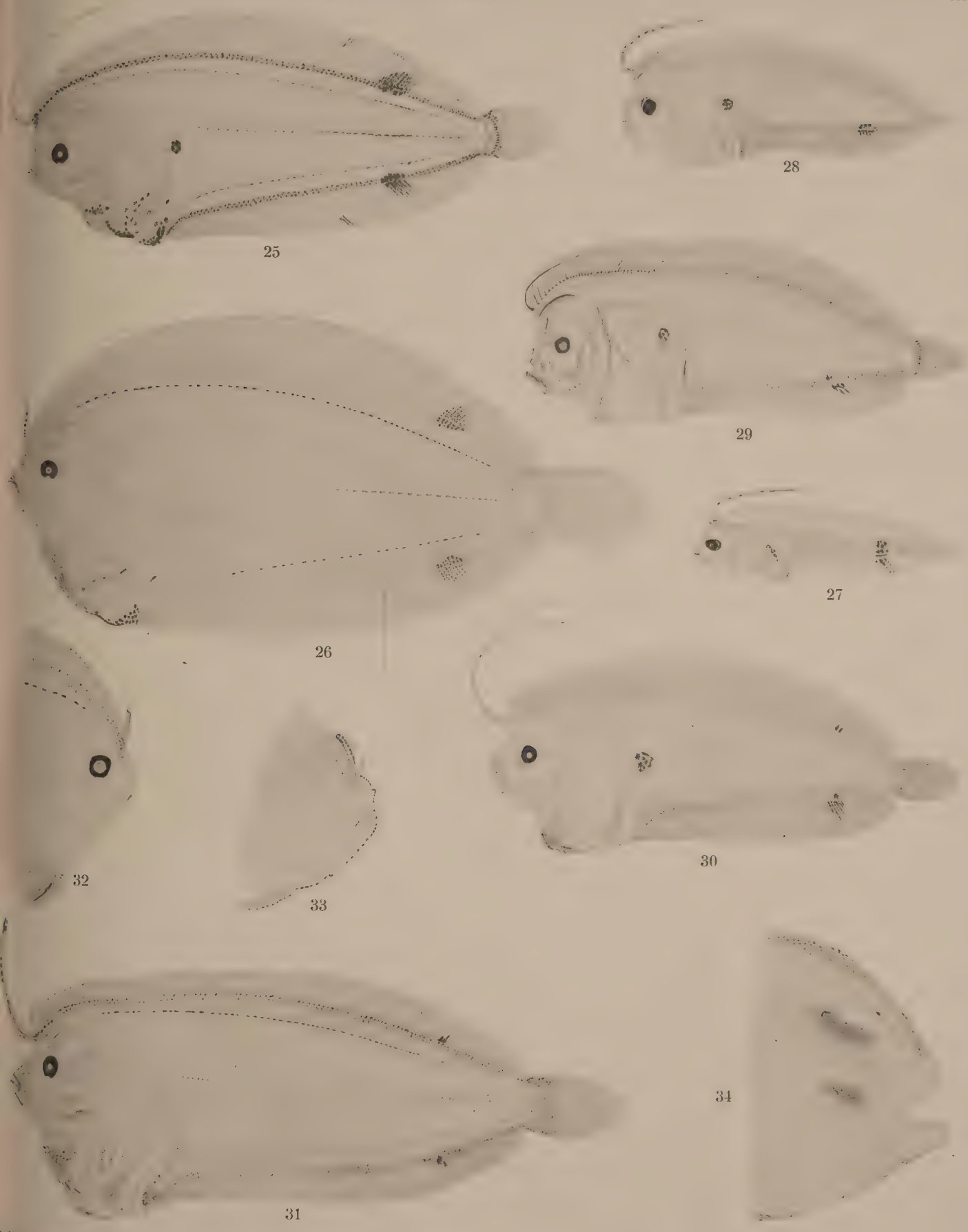
Figs. 1—4. *Arnoglossus Grohmanni* (Bnp.)
— 5—10. — *Thori* (nov. nom.)
Fig. 11. *Arnoglossus imperialis* (Raf.)
— 12. — *Rüppeli* (Cocco)



M. Kyle del

Pacht & Crone phototyp.

Figs. 13—18. *Arnoglossus laterna* Will. form A
— 19—21. — — Will. form B
— 22—24. — *imperialis* (Raf.)



H. M. Kyle del.

Figs. 25—26. *Arnoglossus imperialis* (Raf.)
— 27—31, 34. — *Rüppeli* (Cocco.)
— 32—33. — *Thori* (nov. nom.)

Pacht & Crone phototyp.

Kyle del

Pacht & Crone phototyp.

Fig. 35. *?Solea Capellonis* Steind.
— 36. *Solea variegata* (Don).
— 37. — *lutea* (Risso)

Fig. 38. *Solea Kleini* (Risso)
— 39. — *lascaris* (Risso)
— 40. *?Solea nasuta* (Pall.)

Figs. 41—44. *Symphurus lactea* (Bnp.)
— 45—46. *Symphurus ligulata* (Cocco)

REPORT

ON THE

DANISH OCEANOGRAPHICAL EXPEDITIONS 1908-1910

TO THE

MEDITERRANEAN AND ADJACENT SEAS

PUBLISHED AT THE COST OF THE CARLSBERG FUND

UNDER THE SUPERINTENDENCE OF

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VOL. III: MISCELLANEOUS PAPERS

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REPORT ON THE DANISH OCEANOGRAPHICAL EXPEDITIONS 1908-10
TO THE MEDITERRANEAN AND ADJACENT SEAS
Vol. III. Miscellaneous Papers.

1.

Experiments with drift-bottles

(First Report)

by

Johs. Schmidt.

With 6 Tables and 6 Charts.

Published June 25th 1913.

CONTENTS

I. Introduction 3
II. Earlier experiments with drift-bottles in the Mediterranean 3
III. The Danish experiments with drift-bottles 5
a. Arrangement of the experiments 5
b. The separate experiments 6
c. General remarks on the value of experiments with drift-bottles 8
d. Discussion of the results obtained 10
e. The biological significance of the experiments 13
Tables 14

I. Introduction.

In the introduction to Vol. I of this Report it was stated, that the principal, biological aim of the Expeditions was to investigate the pelagic life, especially the relation between the pelagic fauna and flora of the Mediterranean and Atlantic.

As a natural consequence of this a great deal of work was carried on during both cruises in and around the Straits of Gibraltar, the connecting link between the two seas. The hydrographical investigations discussed in J. N. Nielsen's and J. P. Jacobsen's papers in Vol. I will show this clearly. There the former of these authors discusses the question of the velocity, with which the water inflowing from the Atlantic moves eastwards in the Mediterranean (Vol. I, pp. 170—178).

It seemed to me furthermore of interest to obtain, by direct experiments with drift-bottles, a well-founded estimate of the rate with which pelagic organisms may be carried in the uppermost layers from the Straits of Gibraltar eastwards in the Mediterranean. For this reason such experiments have also been carried out since the beginning of 1912, and the present paper contains a report on the results obtained by them, which deserve to be known, it seems to me, and not least by the biologists, who are engaged in the examination of the material collected on the Expeditions.

I owe my best thanks to Professor F. Buhl of Copenhagen University, to whose linguistic help I ascribe the fact, that comparatively many reports regarding drift-bottles found by Arabs have been received. Further, I have to thank The United Steamship Co. of Copenhagen and the East Asiatic Co. of Copenhagen, from whose vessels the bottles have been thrown overboard, the captains of the vessels, as also the Danish Consul General in Algiers, Dr. Nissen, and the Danish Consuls in Cadiz, Naples and Tunis, Mr. C. Bay, Mr. M. v. Orelli and Mr. H. Ellefsen, all of whom in various ways have rendered valuable assistance in the carrying out of these experiments.

II. Earlier experiments with drift-bottles in the Mediterranean.

One of the most interesting drifts of a current-bottle is the well-known case described by Prince Albert I of Monaco (C. R. 114, 1892) who threw out the bottle in question in the Atlantic S. W. of Ireland at 48° N., 20° W. It was found 646 days later on the coast of Tunis to the west of Bizerta, which shows that its rate of drift has been at least about 5 miles a day and probably even more. This bottle together with some drifting Sargasso-weed in the Western Mediterranean is direct evidence, that floating bodies can be carried into the Mediterranean from remote places in the Atlantic. As we know, the Sargasso-weed comes from the West Indian and American coastal waters. Concerning the velocity of the drift these

records do not tell us much and, as far as I know, only two other bottles have up to the present been recorded as having been carried from the Atlantic into the Mediterranean. The more important of these was thrown overboard from the German warship "Moltke" west of Gibraltar at 35° N. and $7^1/_2$° W. (Annalen der Hydrographie 1897, p. 409) and found again 87 days later in the Bay of Tunis, having travelled 910 miles eastwards at a rate of at least $10^1/_2$ miles per diem.

The first and most important experiments with drift-bottles in the western part of the Mediterranean (Balearic Sea) were undertaken by the French naturalist AIMÉ a little before the middle of the last century.

AIMÉ's work was published in "Exploration scientifique de l'Algérie", Physique Générale I, Paris 1845, where on pp. 186—191 he mentions his experiments with drift-bottles and the currents in the Mediterranean. AIMÉ threw out altogether 50 bottles off the Algerian coast; they were not weighted in any way. Of these 50 bottles sent adrift at different seasons of the year only 3 were reported again (thus 6 %), but these 3 bottles alone gave important information about the direction of the drift, whilst the information they yield about the rate is perhaps less important.

AIMÉ's first bottle was put adrift on the 14th of August 1840 off ("devant") Cape Cherchell (between 2° and 3° Long. E) and was found 88 days later at Ciudadela on Minorca. AIMÉ estimates the average rate at 3 miles (1 lieue) per diem and states, that the drift of this bottle shows the existence of currents which sometimes move northwards in the summer-time, namely in that period when easterly winds are prevalent along the African coast.

The second bottle was put adrift the 15th of August 1840 5—6 miles to the north of Cape Ténès (ca. 1° 20′ E. Long.) and was found 233 days later 4 miles off Cape di Gallo on Sicily near Palermo. The average rate of drift is estimated at 3·3 miles ($1^1/_{10}$ lieues) per diem. AIMÉ was of the opinion that this bottle, which was put adrift almost at the same time as the first, has probably followed the very same route as the former in September—October and then that currents produced by N. W. and W. winds in December—March have carried it back towards the coasts of Africa.

The third bottle was put adrift on the 17th of February 1842 "au Cap Bougaroni" (between 6° and 7° E. Long) and recovered 32 days later at Soliman in the Bay of Tunis corresponding to an average drift of 7·8 miles ($2^6/_{10}$ lieues) per diem. To this AIMÉ remarks, that the west wind is most frequent and strongest along the African coasts in February and March.

From the drift of his drift-bottles and from information given by sailors AIMÉ comes to the conclusion (p. 189), that the great east-going surface current leaves the African coast at Cape Bougaroni (between 6° and 7° E. Long.), where it divides into 3 parts, one in the direction of Syrtis, another going into the Tyrrhenian Sea and the third northwards following the west coasts of Sardinia and Corsica.

Besides, AIMÉ gives some velocities for the stream along the African coast (p. 189); these however are apparently based on too slender a basis to be credited with much value and we may reasonably doubt his statement, that the velocity of the current is less in the Straits of Gibraltar than off the town of Algiers, or that it on the whole is greater between Algiers and Bona than between Algiers and Gibraltar.

A few records of drift-bottles in the Mediterranean are occasionally mentioned in "Annalen der Hydrographie" under the title "Flaschenposten", but they do not give us any picture of the surface drift as a whole; some of them are discussed by KRÜMMEL (Handbuch der Oceanographie, II, p. 622, 1911)[1].

[1] A summary of the reports regarding drift-bottles in the Mediterranean is published by G. SCHOTT in "Die Flaschenposten der Deutschen Seewarte" Hamburg 1897, p. 30. Those recovered later are mentioned in: Annalen der Hydrographie and as far as they refer to the Western Mediterranean basin at the following places: 1899, p. 228 (g) and (h); 1900, p. 498 (i); 1904, p. 184; 1909, p. 333 (5) and (6).

The few and scattered experiments noted above seem on the whole to constitute all that has been done with drift-bottles in the western part of the Mediterranean and certainly no systematic investigations have been carried out. But further eastwards round Italy a great and praiseworthy work has been started from the Italian side and of this we have evidence in the reports of O. Marinelli and G. Platania (Memorie geografiche 1908, No. 5, p. 188 ff), O. Marinelli (Rivista Geograf. Italiana 1909, vol. 16,6), G. Ferruglio (Bolletino del. R. Comitato Talassografico Italiano, No. 17, 1912) and others.

III. The Danish experiments with drift-bottles.

a. Arrangement of the experiments.

I may now proceed to an account of the experiments, which we have carried out during the year 1912 and which in several respects have given a clear result, owing to the fact that a relatively large number of bottles, on an average about 25 %, have been found and recorded.

The bottles were ordinary champagne-bottles, well corked and the mouth afterwards dipped in pitch. In most cases the bottles only held the necessary papers; in some cases (Nos. 601—650) so much sand was put into the bottles that they could just float in water of 36 ‰ salinity. In addition to a numbered post-card, on which the finder was asked to write the necessary particulars, the bottles held a communication to the finder written in different languages. This arrangement seems to have been successful, as is witnessed by the pretty considerable number of reports received.

What I desired to ascertain from the drift-bottle experiments was the rate at which the current moves from Gibraltar and eastwards into the Mediterranean; this, namely, is of great importance for the question of the transport of pelagic organisms from the Atlantic into the Mediterranean and the rate of transport. In so far it would have been preferable to throw the bottles out in or a little outside of the Straits of Gibraltar, and I only resolved on having them thrown out more to the east, between Gibraltar and Cape de Gata, because I feared that most of them might by chance be washed ashore immediately at Gibraltar.[1]

I shall now mention each particular experiment referring at the same time to the tables and charts, where they are also separately specified. With regard to the method of throwing out the bottles not much need be said. Batches of 25 or 50 bottles were thrown out at the same time, strict injunctions being given to the captains to see that all the bottles to be thrown out at a given place, were really put out at the same time. I may give here the account which Captain Jørgensen, S.S. "Nicolai II" has sent me concerning his method of throwing out 50 drift-bottles: "I have the 50 bottles placed on the boat-deck near the bridge. At the fixed time the mate on watch and I go down, take a bottle in each hand and throw them out. This means 12—13 throws for each and in less than one minute the 50 bottles have been thrown out."

On the tables of the separate experiments are specified the places of recovery as well as the names of the finders, if readable. These particulars are given in the original without trying to translate them and with the same detail as received, from the consideration, that detailed information concerning the records might perhaps be of interest for other inquirers, who may wish to go further with the investigations, whilst moreover it is only fair to the finder, who for a small reward has had some trouble, apparently often considerable, in putting down the desired information, that this should be published in extenso.

[1] I have given quite a preliminary and casual reference to the first of these experiments in the "Internationale Revue der gesamten Hydrographie", vol. V. Leipzig 1912, p. 331 Note.

In the column next to the place of recovery is noted the approximate position of each, in the next the distance between the place of liberation and the locality where found, measured on a somewhat small map and consequently without claim to great accuracy, this being less important considering the other great sources of error in these experiments. The next column shows the number of days between the day of liberation and the day of recovery, only one of these days being included in the total.

In the Mediterranean experiments mentioned here we have on an average reached about 25 % recorded bottles, almost all of which have been recovered within the lapse of half a year after the day, on which the bottles were thrown overboard, the majority after a few months. Thus we get no information about the bulk of the bottles. Naturally we may perhaps still obtain a few records of bottles washed up on uninhabited coasts or on coasts only occasionally frequented, as for instance parts of the exceedingly long coastal stretches of Tripoli and Barka, which are most likely a burial ground for many of our bottles. We may assume that the remainder of the bottles have either been smashed in the surf on rocky coasts or sunk to the bottom from one or other cause before reaching the coasts.

b. The separate experiments.

Experiment No. 1 (see chart No. 1).

Of the 50 bottles thrown overboard on January 9th, 1912, east of Gibraltar about in the middle of the Alboran Sea (36° 06′ N. 4° 30′ W.) from the Danish S. S. "Nicolai II", Captain Jørgensen, we have received information about 10 bottles, thus 20 %, up to the end of the year 1912. All the bottles have been found further east than the spot where they were put overboard, between 3° 53′ W. and 11° 29′ E. With exception of one bottle (No. 44), which was washed ashore on the south coast of Spain near Almeria, all the others were recovered along the coast of Africa, in Morocco (2), Algeria (4), Tunis (3) and we thus see that they have followed the inflowing Atlantic water, which in its least mixed condition keeps close to the north coast of Africa during its east-going movement.

For the rate of drift of the bottles, we must in the first place investigate the drift of those, which have moved most quickly. On the table p. 14 the minimum average rate per diem is given in the third last column, which shows, that the bottle No. 17, 48 days after being thrown out, was found 705 miles further east on the coast of Tunis to the north of Bizerta; thus it has drifted with an average rate of 14·7 miles per diem at least, perhaps considerably more, for in the first place it has possibly not been found immediately after being washed ashore, secondly it is probable that it has not followed the shortest route between the spot where put overboard and the spot where found, from which the velocity is calculated. The other 9 bottles all show a far smaller velocity and this is probably due, in the case of those (Nos. 32 and 30) washed ashore on the coast of Morocco undoubtedly due, to their not being found until long after by the scattered dwellers of the coast. It is seen from this, that nothing can be concluded from the recovery of one of the bottles, but that a larger number is necessary before we can obtain values for the rate of drift approaching the reality, a view confirmed also by the other Danish experiments with drift-bottles.

Experiment No. 2 (see chart No. 2).

Of the 50 bottles set adrift on January 9th 1912 in the eastermost part of the Alboran Sea (36° 20′ N., 2° 30′ W.) from the Danish S. S. "Nicolai II", Captain Jørgensen, we have received information about 14 before the end of the year 1912, thus 28 %.

All the bottles were found on the northern coast of Africa and at spots lying further east than the place of liberation, namely between 1° 14′ W. and 11° 08′ E.; of these 6 were recovered in Algeria, 8 in Tunis.

Most likely they have therefore all followed the Atlantic water eastwards along the northern coast of Africa.

As with the previous experiment, to get an estimate of the velocity, we must take the drift of that or those bottles which have moved most quickly; special prominence must be given to No. 73, which was found at Kélibia in Tunis and has thus passed over a distance of at least 700 miles, this with a minimum rate of 19·3 miles a day; thus somewhat greater than that of the first experiment. There are several other bottles of experiment 2 the drift of which is almost the same as that of bottle No. 73, in particular No. 56 which was recovered 605 miles further east on the coast of Tunis, having moved at a rate of at least 16 miles per diem.

Experiment No. 3 (see chart No. 3).

Of the 25 bottles set adrift on May 13th 1912 in the central part of the Alboran Sea about 25 miles south of the south coast of Spain (36° 24′ 5″ N., 3° 30′ W.) from the Danish S. S. "Pangan", Captain Chr. Schmith, 6 have been recovered up to the end of the year 1912, thus 24 %.

All the bottles were recovered E. of the spot where they were set adrift, between 2° 53′ W. and 6° 53′ E.; of these 2 were recovered on the south coast of Spain, the remaining 4 on the coasts of Algeria. These 4 have thus, like so many other bottles in previous experiments, followed the inflowing Atlantic water along the coast of Africa. In this experiment the greatest velocities are 11·5 and 11·3 miles a day for two bottles (No. 504 and 507), found on the same day (June 6th 1912) almost at the same place on the coast of Algeria at ca. 2° 10′ E. From this agreement between these two bottles one might be inclined to believe, that the rate of movement has really been approximately about 11 1/3 miles on an average, but this velocity is less than that found in the two previous experiments and their recovery at the same time and place is perhaps only due to chance.

Experiment No. 4 (see chart No. 4).

Of the 25 bottles set adrift on May 13th 1912 in the easternmost part of the Alboran Sea near Cape de Gata (36° 42′ N., 2° 01′ W.) from the Danish S. S. "Pangan", Captain Chr. Schmith, 11 have been recovered up to the end of 1912, thus 44 %. All the bottles were found to the east (between 0° 07′ W. and 11° 10′ E.) but there is a difference here from previous experiments in that only a small number of the bottles (2) were recovered on the coast of Africa, one of them on the Algerian coast, the other on the Tunisian, while 5 were recovered on the Balearic Islands and 4 on the east coast of Spain. The rate of drift of the bottles, which followed the African coast, is best seen from bottle No. 550, which stranded near the town of Algiers having passed over 255 miles in 14 days, corresponding to a minimum rate of 18·2 miles per diem. On the other hand, the rate of drift of those bottles which after leaving the Alboran Sea have drifted to the east coast of Spain is apparently considerably less. Thus, we apparently find the smallest rate of drift in the bottles found on the east coast of Spain, namely, from 2·2 to 3·2 miles per diem (calculated from the shortest distance). The bottles which landed on the Balearic Islands show a somewhat greater velocity, from 2·5 to 5·2 miles per diem.

This experiment seems thus to indicate that the velocity of movement is greatest towards the east, decreasing as it turns north-east and north.

Experiment No. 5 (see chart No. 5).

Of the 25 bottles set adrift on August 1st 1912 near Cape de Gata (the easternmost portion of the Alboran Sea, at 36° 40′ N., 1° 59′ W.) from the Danish M. S. "Selandia", Captain Gabe, information has been received from about 8 bottles up to 31st May of 1913, thus 32 %. They were all recovered further east than the spot where they were thrown overboard. Only three of these bottles, Nos. 628, 642 and 644, were recovered on the coast of Africa where they were washed ashore on the Tunisian coast; three of the others were washed ashore on the Balearic coasts and two on the east coast of Spain. Regarding the rate of drift this experiment does not seem to indicate much of importance.

Experiment No. 6.

Of the 25 bottles thrown out on August 1st 1912 near Cabo de Palos on the southern part of the east coast of Spain (37°38′ N., 0°28′5″ W.) by the Danish M. S. "Selandia", Capt. Gabe, 8 i. e. 32 % had been recovered by the end of the year 1912. In contrast to all the other experiments none of the bottles had drifted long distances. They were all found within 30 miles of the place where they were thrown out and in the course of about 1 month. Calculated according to the shortest distances, the rate of drift lies between ca. 1/2 and ca. 1 1/2 miles per diem. It is worth observing that the 2 bottles (Nos. 611 and 615), which showed the greatest rate of drift, were found floating in the sea by Spanish fishermen. Both bottles showed a rate of drift of about 1 1/2 miles per diem and it is possible, therefore, that this small rate of drift corresponds to the real velocity of the current in the sea close to the southern part of the east coast of Spain during the summer. The other 6 bottles were all found on the shore and in agreement herewith they all showed a still smaller rate of drift than the 2 bottles taken out at sea.

The directions in which the bottles have drifted lie between N. and W. Owing to the short distances I find it unnecessary to mark the route on a chart as has been done for the other experiments.

c. General remarks on the value of experiments with drift-bottles.

In drawing conclusions from drift-bottle experiments, we must necessarily proceed with the greatest caution as the sources of error are numerous and serious. It is thus a matter of course, that with the material at our disposal, i. e. knowledge of the two extreme points of the drift, place of liberation and place of recovery of the bottle, and the interval of time between, there can be no talk of determining with certainty either the route followed by the bottle or the rate of drift it has actually had. We are at the most able to determine the probable route and, considering this to be the shortest possible, the minimum rate of drift over the distance covered (calculated for example per diem or per hour). The more bottles found and the greater agreement in their drift the greater is of course the probability that our calculations approach reality.

In discussing the value of experiments with drift-bottles reference has often been made to the influence that may be exercised by the wind on their direction and rate of drift. It has even been maintained, that these will sail with the wind instead or drifting with the current, the result of which would be, that the desired information regarding the direction and velocity of the current cannot be obtained by these experiments with drift-bottles. Here, however, there is undoubtedly considerable exaggeration as regards the influence of the wind, though it may have some influence, and its amount will naturally depend on the construction and weight of the bottles and thus their height above the water.

I shall not enter however into a discussion of what may be said for and against in this regard, but be content with quoting Krümmel's judgment. After discussing the value of drift-bottle experiments in this section of his recently published Handbuch der Oceanographie II, 1911, p. 437, the latest standard work on the subject, he remarks: "We know now that the bottles even without sand-ballast float deep enough to drift mainly with the current and not merely with the wind, quite apart from the fact that the direction of both does not generally differ much in the open sea." That drift bottles may move against the prevailing wind even when the current is weak and whether they are ballasted or not, has been proved by G. Schott especially (Die Flaschenposten der Deutschen Seewarte p. 19, Hamburg 1897)[1], to whom we are indebted for some very important papers on drift-bottle experiments carried out on the initiative of the "Deutsche Seewarte" in Hamburg.

[1] We may also mention here the very extensive experiment with drift-bottles which was carried out by G. Gilson from the light-ship West-Hinder, and which showed that the drift of the bottles is in the main uninfluenced by the wind (Mémoires Musée Royal d'Historie Naturelle de Belgique, Bruxelles 1900 and 1901).

To obtain the best possible result we may proceed in various ways, as for example by trying as much as possible to counteract the direct influence of the wind on the drift-bottles. This may be done by making the bottles so heavy that they project as little as possible above the surface, e. g. by using sand ballast or by coupling two bottles together, the one filled with water, or finally by using other objects (balls, barrels etc.). Further, we may endeavour to get information regarding the meteorological conditions at the places and times in question, information that is often very easily obtained, especially by setting the bottles adrift on very frequented routes or along coasts where meteorological stations occur.

As already mentioned, bottles with sand ballast have been used to a great extent in the Danish drift-bottle experiments in the Mediterranean and one of the experiments going on at the present time is directly intended to ascertain whether there is any difference in the drift of such bottles and bottles without ballast. The results however will only be discussed in the second report on the drift-bottle experiments.

On the other hand, an endeavour may be made here to utilize the meteorological observations in drawing conclusions as to the influence of the wind on the drift. For this purpose it will be of advantage to choose a bottle which on the one hand has drifted most quickly and on the other hand has only covered a short distance (the conditions being thus more readily understood). We may thus take bottle No. 550 (Experiment No. 4) which on May 13th 1912 was thrown out in the neighbourhood of Cape de Gata (Andalusia) and on May 27th 1912 was found on the coast of Africa near the town of Algiers. This bottle has thus covered 255 miles in 14 days at the most, corresponding to an average velocity of at least 18·2 miles in the 24 hours. We must now investigate whether this considerable minimum velocity may possibly be due to exceptional meteorological conditions or not. We naturally direct our attention first of all to the strong,. prevailing winds from the west which might be supposed to have hastened the movement, partly by acting directly on the bottle, partly on the surface water in which it was floating, the east-going movement of the water being thereby increased to an exceptional extent.

When the bottle was thrown into the water of Cape de Gata the wind and sea were E. 5 and thus cannot have influenced the drift in the opposite direction. Dr. J. N. Nielsen of the Meteorological Institute of Copenhagen has rendered me the service of studying the Algerian meteorological charts (Bulletin météorologique de l'Algérie) for the period from May 13th to May 27th 1912 and he informs me that with the exception of 3 days (21st—23rd May), when fresh or stiff western and north-western winds were blowing, the winds prevailing over the south-western Mediterranean during the period in question were light and variable and that the meteorological conditions in this part of the Mediterranean were on the whole very calm.

Further, Prof. G. Schott of Hamburg has kindly sent me copies of meteorological observations carried out for the "Deutsche Seewarte" by various German vessels on the route from Cape de Gata to Algiers, besides which I have had some observations by Danish vessels taken on the same route. On the days from which few or no ships' observations are to hand, namely the 19th, 21st and 27th of May, Prof. Schott has been so kind as to send me a copy of the meteorological observations taken at Spanish and French meteorological stations near the route followed by the drift bottle (i. e. Cape de Gata, Algiers, Oran, Némours, Alicante and Palma on Majorca).

Altogether 85 observations from vessels are available, distributed fairly evenly over the period from May 13th to 27th on the route from Cape de Gata to Algiers. First and foremost they show that the weather has generally been very calm throughout this period. No gale or storm is noted and only 4 times does the force of the wind reach 7 Beaufort (E. N. E. 7; W. 7; W. 7; W. S. W. 7). Regarding the direction of the wind 32 of the 85 observations indicate winds from the west (between N., W. and S.) with an

average force of 3·7 Beaufort and 42 winds from the east (between N., E. and S.) with an average force of 3·5 Beaufort, while 11 observations indicate winds from N. or S. or calm. I have arranged these observations in the following table, dividing the distance from Cape de Gata to Algiers into two parts, one to the west (W) and one to the east (E) of 0° Long. Greenwich. For the few days on which no observations are to hand, I give the observations from the nearest meteorological station.

Summary of wind observations made by vessels on the route from Cape Gata to the town of Algiers during the 13th—27th of May 1912.

May 1912	Cape de Gata — 0°	0° — Algiers	May 1912	Cape de Gata — 0°	0° — Algiers
13	E. 2—5	E. 1, W. 1	21	(2)	(3)
14	E. 3	W. 5—6	22		W. 4—7
15	W. 2—3	W. 1—7	23	W. 2—6	W. 5—7
16	E. 1, W. 1	E. 2, W. 1	24	W. 4	E. 1—5
17	E. 3—6	E. 2—7	25	E. 4, W. 2	E. 2, W. 2—3
18	E. 5—6½	E. 3—4	26	E. 2—4, W. 2	E. 2
19	(1)	W. 3	27	(4)	E. 2—3
20	Variable 2—3; W. 4	E. 2—3			

1) Stations on land: variable winds, force 1—4.
2) Stations on land: variable winds, force 1—5.
3) Algiers S. S. E. 3 and W. 5.
4) Stations on land: variable winds, force 1—4.

Note. Statements such as "E. 2—5" mean that all observations made on the day noted indicated winds from the east, which at the different places of observation varied in force between 2—5 Beaufort.

From the above data it is undoubtedly evident, that no exceptional meteorological conditions prevailed while the bottle was drifting from Cape de Gata to Algiers. The winds were variable, everywhere changing frequently from E. to W., from which we may draw the conclusion, that their effects both directly on the bottle and on the surrounding water must to a certain extent have neutralized each other. It follows from this, that the average rate of drift observed, i. e. 18·2 miles per diem, must in reality correspond to the velocity at which the surface water, irrespective of the wind, moved eastwards or rather it must be at least as great; for even if the bottle has probably been found immediately after being thrown on land, it is not very likely that it should just have covered the shortest way between the 2 points. We thus see that the velocity of the current irrespective of the wind may here reach up to about 20 miles at least per diem and we must further reckon with the possibility, that if strong westerly winds are blowing regularly for some time it may attain to a still greater velocity.

d. Discussion of the results obtained.

As a first result of all the experiments made in 1912 we may note that one and all of the bottles have moved in the direction from the Atlantic towards the Mediterranean, irrespective of the time of year at which they were thrown out.

While the surface water in the Alboran Sea itself for topographical reasons must in the main be considered to be in motion from W. to E.[1], the water after having passed this sea seems, at any rate in summer, to spread out like a fan over the Balearic Sea between Africa and the east coast of Spain, but with different velocities in the various current-branches. Thus the velocity is undoubtedly greatest in the most east-going part of the current following the coast of Africa, where an average velocity of about 20 miles has been observed under such conditions, that we may draw the conclusion that the current had

[1] Close under the coast of Andalusia there must be at any rate at times coastal currents towards the west, as is indicated by the German drift bottle mentioned in the note on p. 11 and the small rate of drift (0·8—3·2 miles per diem) of our drift-bottles Nos. 44, 511 and 512 which landed on this coast.

at least so great a velocity. On the other hand, the velocity of the current seems to decrease greatly the more it is directed N. E. and N. and thus to be least nearest the Spanish east coast. This is evident from our experiments Nos. 4, 5 and 6, which seem to show that the rate of drift of the bottles is greater further towards the east (Majorca and Minorca) less near Iviza and least off the Spanish east coast, all under the supposition that they have not made great detours (see below). I may thus refer to bottle No. 546 found drifting E. of Majorca (average rate of drift 5 miles per diem) and to bottles Nos. 611 and 615 found floating near the east coast of Spain off Alicante (average rate of drift for both 1·5 miles per diem).

As already known (see J. N. Nielsen's paper in Vol. I of this report) we are indebted to the English Admiral W. H. Smyth (The Mediterranean, London 1854, pp. 161 et seq.) for the first complete account of the current conditions. Later authors have in the main based their current-charts on this work. According to Smyth, the movement of the surface water in the western basin of the Mediterranean is cyclonic: along the south coast east-going, along the Italian west coast north-westerly, along the north coast westerly and along the Spanish east coast south-westerly, thus completing the circuit.

While our experiments very clearly display the east-going movement along the coast of Africa, they seem on the other hand to be opposed to a south-westerly movement between the Balearic Isles and the east coast of Spain. It might of course be supposed, that those bottles which stranded on the east coast of Spain have first drifted eastwards and have then after a detour towards the north, north-west, west and south-west been thrown up on the east coast of Spain. This is the explanation Krümmel, l. c. p. 622, was disposed to give in his discussion of Aimé's drift bottles and some of the "Deutsche Seewarte"s bottles[1]. He is most probably right, but we may then draw the conclusion, either that our drift-bottles which landed on the east coast of Spain have made a detour eastward round the Balearic Isles or that the direction of the current between the Balearic Isles and Spain must be quite different in summer and winter. Both conditions are perhaps possible. Our experiments (Nos. 4, 5 and 6) give no direct evidence of a south-going movement along the east coast of Spain. From experiment No. 6 when the bottles were thrown out near Cape de Palos it is seen, that during the summer time there is a slow north-going current close under the Spanish east coast. It may also be of interest in this connection to consider the surface salinities observed by Dr. Nielsen during the second "Thor" expedition in the last days of August and the first days of September 1910 round the Balearic Isles and between Valencia Bay and Algiers. As seen from Chart 6 on which the data are given, the salinity increases slowly from the southern part of Valencia Bay to off Barcelona, i. e. from 37·56 ‰ to 37·90 ‰, a condition which agrees quite well with the supposition that there is sometimes a slow north-going movement along the Spanish east coast, whereas it might possibly be more difficult to explain if the water had circulated in the Balearic Sea by means of a cyclonic movement.

The salinity is also of importance in another direction, which I may also point out here. It is seen from the figure, that the lowest value 36·74 ‰ is observed quite close to the coast of Algeria and and also that the salinity towards the N. W. first increases very slowly (up to 36·89 ‰) then somewhat more quickly (to 37·22 ‰ south of Iviza) then again more slowly up to St. 214 almost in the middle of Valencia Bay (37·79 ‰). This increase in salinity from south to north is apparently in full agreement with the rates of drift observed in our experiments, especially No. 4, which just showed by far the greatest value in the southern part of the region near the coast of Africa and were greatly on the decrease

[1] Thus one bottle was thrown out on 21/10 1898 at 38° 59′ N., 0° 51′ E. and recovered on 27/11 1898 at 37° 50′ N., 0° 44′ W. (Annal. d. Hydr., 1899, p. 288), another thrown out on 17/1 1899 at 37° 44′ N., 3° 27′ E. was found again on 18/10 1899 at 41° 09′ N., 1° 36′ E. drifting in the sea, (Annal. d. Hydr. 1900, p. 498, a third thrown out on 22/6 1908 at 37° 36′ N., 7° 42′ E. was found again on 24/9 1908 at 37° 36′ N., 0° 42′ W. (Annal. d. Hydr., 1909, p. 333). A fourth bottle thrown out on 28/12 1908 at 36° 24′ N., 4° 48′ W. and found again on 7/1 1909 at 36° 24′ N., 5° 06′ W. indicates a slow drift in a westerly direction close under the coast of Andalusia.

in the more north-east and north-going branches of the current. It is evident, namely, that the greater the velocity of the inflowing Atlantic water the less will it mix with the salter Mediterranean water and conversely.

If we thus, seemingly, have found a movement from south to north in the waters between the Balearic Isles and Spain, it must be pointed out that the experiments in question were carried out in summer when slight winds from S. and S. E. are prevalent here. In winter the winds blow strongly from the N. W. and may well set up a movement contrary to the direction we apparently observed in summer[1]. This may possible by indicated by bottle No. 649. It was thrown out on Aug. 1st 1912 near Cape de Gata and not found again till Jan. 15th 1913 drifting in the sea only about 55 miles from where it had been thrown out. Thus, it is not improbable that to begin with it has floated a long way towards the N. like all the other bottles thrown out at the same time and that together with the water there it has been driven back, to near the place where it was thrown out, by the N. W. winds of the winter time. This is however a mere supposition which cannot be verified and we are thus at present unable to give a satisfactory proof, that those of our bottles which landed on the east coast of Spain went directly to this place without making greater or smaller detours eastward round the Balearic Isles.

That an east-going current is constantly flowing into the Mediterranean, as already indicated in 1887 by G. Schott (l. c. 19) from the few German drift-bottle experiments, has been amply confirmed by our experiments. Whether the velocity of the current varies greatly with the time of year, we have not sufficient data to be able to decide with certainty. That the velocity along the African coast may in spring reach an average value of at least about 20 miles per diem has been proved by the drift of bottle No. 550, and the particular conditions of its drift show, that the velocity must for the most part be considered to have been independent of the influence of the wind. It is therefore most probable, that still greater velocities may occur when constant and strong winds from the W. are predominant. The velocities found by the summer experiments are somewhat smaller than for the winter experiments, but whether this is accidental or not, I am unable to say.

It is at the present time impossible to say for certain, whether a drift-bottle thrown out in the Alboran Sea will follow the African coast or drift more towards the N. E. or N. To judge from our experiments, however, the latitude at which the bottle is thrown out seems to be of some importance in this respect. Of the bottles thrown out further north in the Alboran Sea at any rate a greater proportion took a north-easterly course than of those thrown out further south. It is however also possible, that the time of year may have some influence on the direction of the drift and that a bottle will in winter have a greater chance of following the African coast than in summer, in other words, of being more quickly carried further into the Mediterranean than in summer. At the present stage of the investigations, as already mentioned, nothing definite can be said in this matter. Nor do we know anything definite about the breadth (in the direction N.—S.) of the quickly moving part of the current following the coast of Africa. That the time of year may also be of some importance here, is quite possible. I shall in this connection mention Aimé's bottle No. 1 thrown out on Aug. 14th off Cape Cherchell on the coast of Algeria and recovered on Minorca. If Aimé's designation "devant" Cape Cherchell may be understood as close off this Cape the result would be, unless the bottle has made a wide circuit, that the east-going current along the coast of Africa may at times have a very small breadth during the summer. I know of no winter experiment, which indicates such a small breadth, but at that time of year, when strong westerly and north-westerly winds prevail, it may possibly also be more difficult for a drift-bottle to get out of the east-going current along the coast of Africa than in the summer.

[1] Regarding the wind conditions see e. g. Aimé l. c. p. 190 and Deutsche Seewarte: Wind, Strom, Luft und Wassertemperatur auf den wichtigsten Dampferwegen des Mittelmeeres (Beilage zu den Annalen der Hydrographie, Hamburg 1905).

e. Biological significance of the experiments.

It must naturally be of great biological importance, that surface water from the Atlantic is at all times of the year flowing into the Mediterranean. The result is, namely, that the Mediterranean may receive from the Atlantic a large inflow of pelagic organisms belonging to the upper water-layers, whereas on the other hand no passive transport of surface organisms can take place from the Mediterranean to the Atlantic.

With regard to the westernmost part of the Mediterranean, i. e. the Alboran Sea, the coastal waters just south of Andalusia excepted, if older pelagic surface-organisms, i. e. organisms only living in the upper layers, are found there, we may reasonably conclude that they originate from the Atlantic in most cases.

With the velocities shown of at least 18—20 miles per diem for the Atlantic water following the coast of North Africa, there is also the possibility of a rapid drift of pelagic organisms from the Atlantic far eastwards into the Mediterranean at least as far as to ca. 11° Long. E. On the other hand, our experiments do not suggest any rapid drift from the Atlantic up to places along the Spanish east coast.

It is not yet certain either whether the drift from the Alboran Sea proceeds directly towards the Spanish east coast or indirectly after a detour round the Balearic Isles. On the Charts the drift is noted as direct.

To the organisms which are more or less passively carried into the Mediterranean with the inflowing Atlantic water one of the following eventualities may be deemed applicable:

1) They are quickly killed by the altered natural conditions, and as they thus only reach a short way into the Mediterranean they are of no importance for the life of this sea.
2) They are able to thrive and grow in the Mediterranean but do not find the outer conditions suitable to their propagation. The result is therefore that in the course of a shorter or longer time they perish or in the case of animals able to undertake certain migrations, they seek back to the Atlantic to propagate there.
3) They are able to thrive and propagate in the Mediterranean in spite of the altered conditions and this group of organisms therefore consists of species common to (i. e. indigenous to) the Atlantic as well as to the Mediterranean.

The biological material so far worked up has yielded representatives of all these 3 groups.

12. VI. 1913.

Experiment No. 1

(bottles No. 1—50).

Liberation: Position 36°06′ N., 4°30′ W. Date 9. Jan. 1912, 1[00] a. m. Wind WNW 5. Sea WNW 5

Recovery

No. of bottle	Locality	Position (approximate)	Date	Shortest distance of drift in miles	No. of days	Average rate of drift per diem in miles	Finder	Remarks
9	Plage de Boudjadar, Commune de Lourmel, Département d'Oran; Algérie.	35° 30′ N.; 1° 15′ W.	8. March 1912	165	59	2·8	Jean Hernandez, Lourmel, Algérie	
17	Plage au nord de Bizerte, entre le Cap Blanc et le phare du Ras Engela, à 18 kilom. de Bizerte; Tunisie.	37° 16′ N.; 9° 53′ E.	26. Feb. 1912	705	48	14·7	Mohamed ben Sélema, mine du Djébel Gozlem, Bizerte, Tunisie	
23	Soliman, Golfe de Tunis, Tunisie	36° 44′ N.; 10° 29′ E.	3. June 1912	740	146	5·1	Raffaele Caci. Tunis, Tunisie	
25	Presqu'île de Cap Bon, au lieu dit Oued Seggag; Tunisie	37° 04,5′ N.; 11° 02,5′ E.	27. June 1912	760	170	4·5	Contrôleur civil de Grombalia, Tunisie	
28	Golfe de Bône, entre le Cap Rosa et la rivière Mafray, à la plage; Algérie	36° 58′ N.; 8° 14′ E.	29. May 1912	615	141	4·4	Bouhadja, Mohamed ben Saïd, Bône, Algérie	
29	Plage de l'Oued el Kébir, à la Marsa, commune mixte de l'Edough, arrondissement de Bône; Algérie	37° 05′ N.; 7° 11′ E.	22. May 1912	565	134	4·2	Djémeoun Salah ben Rabah, Douar Ras-el-Hadid, près Herbillon, Algérie	
30	Campo moro cebadilla, Bocoyo (Alhucemas), mar de poniente; Marruecos.	35°15′ N.; 3°50′ W.	10. March 1912	65	61	1·1	Moro Benaod Benamar Libero, Alhucemas, Marruecos	
31	Plage au Ravin des Voleurs, entre Zéralde et Sidi-Ferruch; Algérie	36°43′ N.; 2°49′ E.	20. April 1912	360	102	3·5	Camille Gaillard, Sidi-Ferruch, Algérie.	
32	Playa del Morro Viejo, costa de Bocoya del Riff entre Alhucemas y el Peñon de Vela Malaga; Marruecos	35°13′ N.; 3°53′ W.	1. March 1912	60	52	1·2	Il Aquil ben Abdela z. o. Mohamed Candon, Tetuan, Marruecos	
44	Á un kilometro levante de Faro de Capo de Gata; España	36°43′ N.; 2°12′ W.	19. May 1912	110	131	0·8	Francisco Rodriguez; Cabo de Gata, Almeria, España	

Experiment No. 2

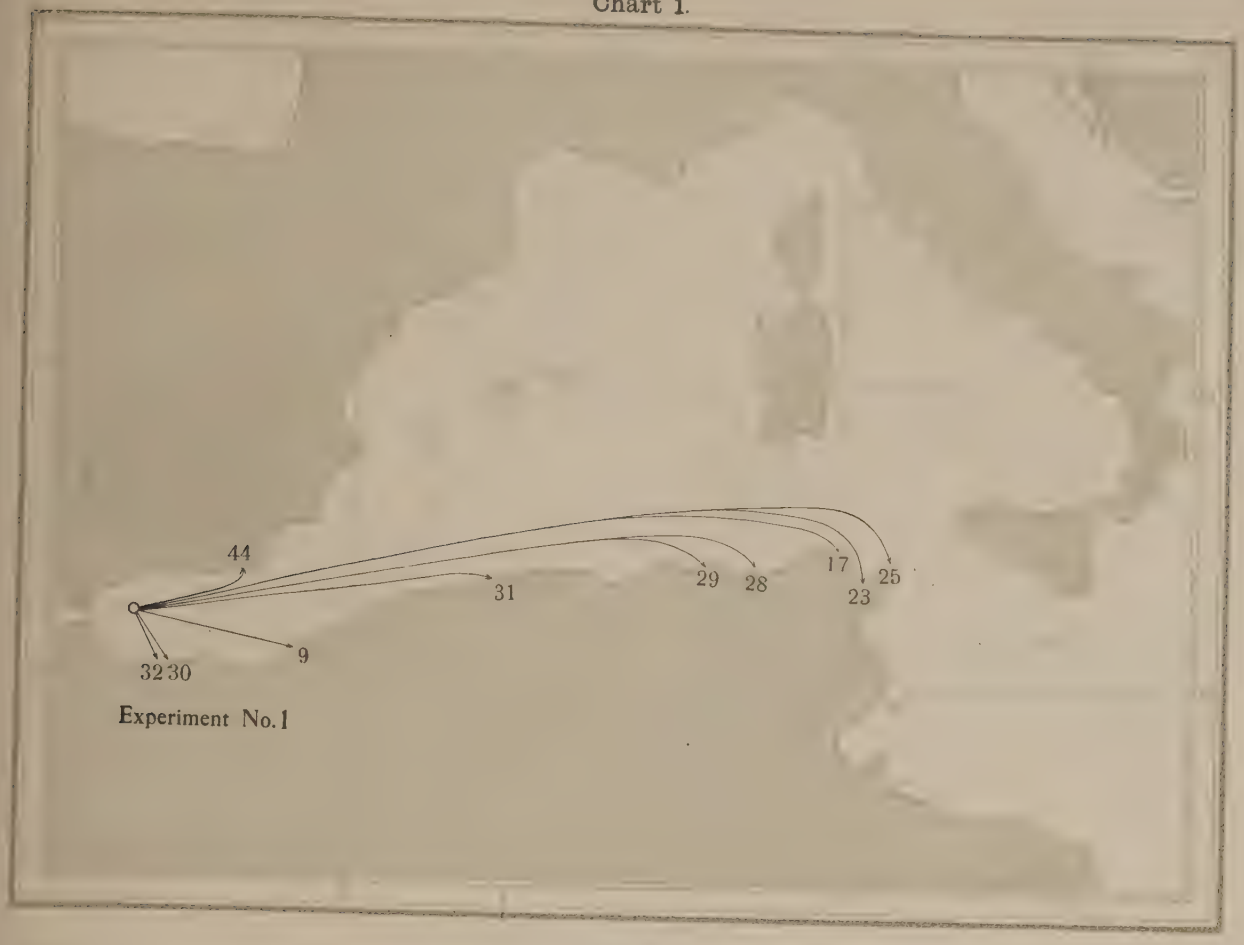
(bottles No. 51—100).

Liberation: Position 36°20′ N., 2°30 W. Date 9. Jan. 1912, 12[30] p. m. Wind WNW 5. Sea WNW 5.

Recovery

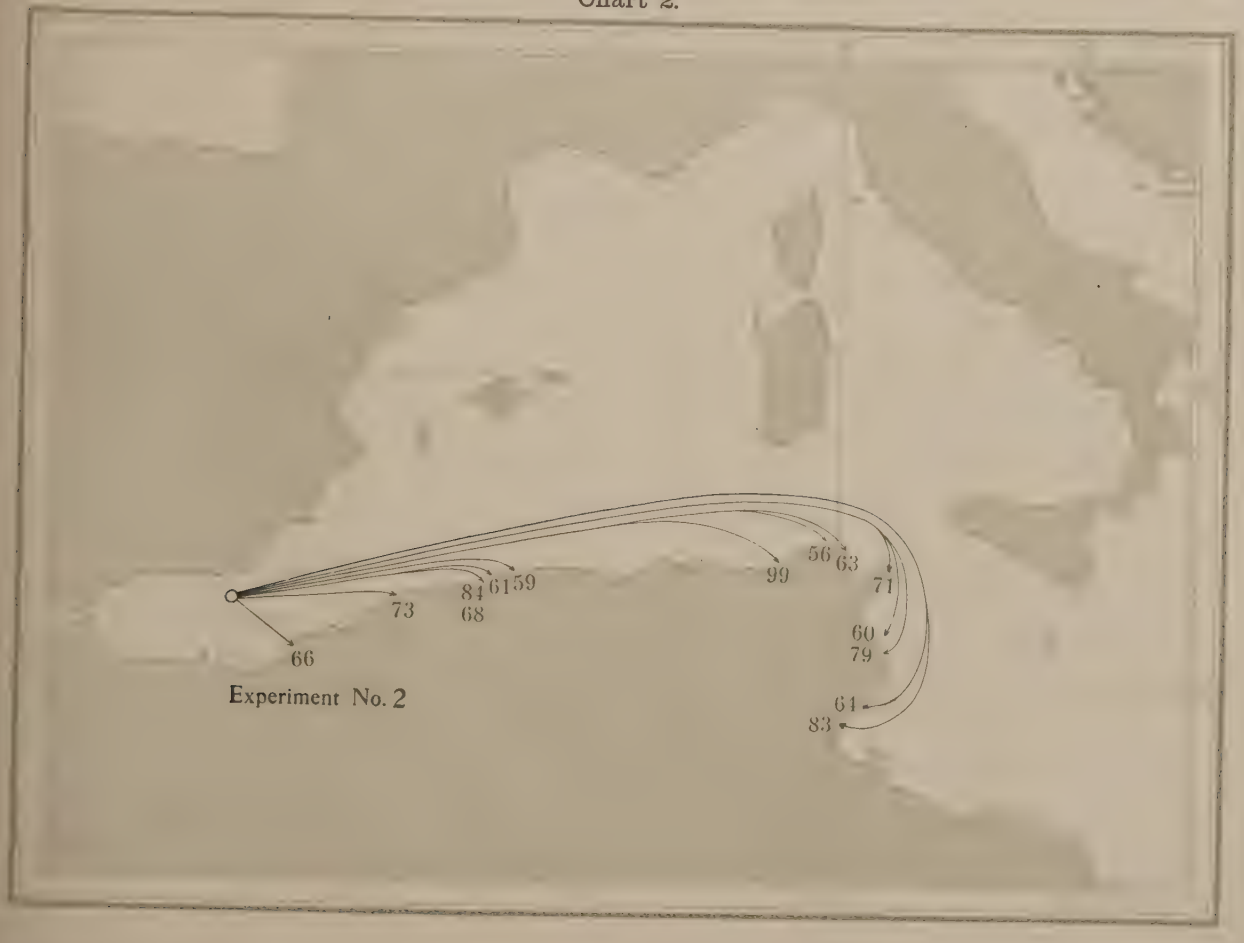
No. of bottle	Locality	Position (approximate)	Date	Shortest distance of drift in miles	No. of days	Average rate of drift per diem in miles	Finder	Remarks
56	Plage comprise entre le Cap Blanc et le phare du Ras Engela, près de Bizerte; Tunisie	37°20′ N.; 9°51′ E.	16. Feb. 1912	605	38	16·0	Mohamed ben Allègue, Mine de Béchatar, par Bizerte, Tunisie	
59	Surcouf (Aïn Taya), Départément d'Alger; Algérie	36°47′ N.; 3°17′ E.	31. Jan. 1912	280	22	12·7	Bertin Pichaud, Surcouf, Algérie	
60	Ile Kuriat; Tunisie	35°48′ N.; 11°02′ E.	29. April 1912	745	111	6·7	Louis Waroeguier, Monastir, Tunisie	
61	Douaouda Marine près d'Alger; Algérie	36°42′ N.; 2°42′ E.	3. Feb. 1912	250	25	10·0	François Molto; Douaouda Marine, Algérie	
63	Dans l'eau mais une dizaine de mètres du rivage sur la plage de Porto Farina; Tunisie	37°13′ N.; 10°12′ E.	16. March 1912	625	67	9·3	Émile Muscat, Porto Farina, Tunisie	
64	Sulla spiaggia di Bouneda vicin. Maharès, circa 18 miglia da Sfax; Tunisie	34°31′ N.; 10°33′ E.	27. May 1912	840	139	6·0	Ali ben Hamsa, Sfax, Tunisie	
66	Cap Figalo, près Lourmel; Algérie	35°30′ N.; 1°14′ W.	29. Jan. 1912	85	20	4·3	Dominian Torregrosa, Lourmel, Algérie	
68	Douaouda près d'Alger; Algérie	36°42′ N.; 2°42′ E.	31. Jan. 1912	250	22	11·4	M. Roncallo, Douaouda, Algérie	
71	Point L'Oued Boularou-ah, environ 2 kilom. de l'île Colombie, par Ténès; Algérie	36°27′ N.; 0°56′ E.	27. Jan. 1912	165	18	9·2	Leonce Cotinaud, Boularou-ah par Ténès, Algérie	
73	Kélibia, près nouvelle adouane; Tunisie	36°52′ N.; 11°08′ E.	14. Feb. 1912	695	36	19·3	Ali ben Mohamed Khoudja, Kélibia, Tunisie	
79	Sur la plage nord de la mer de Mahdia; Tunisie	35°32′ N.; 11°05′ E.	6. June 1912	765	149	5·1	M. Perrin, Mahdia, Tunisie	
83	À la Skira, par Sfax; Tunisie	34°15′ N.; 10°08′ E.	17. June 1912	865	160	5·4	M. Sauvaguac, la Skira par Sfax; Tunisie	
84	Douaouda Marine près d'Alger; Algérie	36°42′ N.; 2°42′ E.	7. Feb. 1912	250	29	8·6	François Molto, Douaouda Marine, Algérie	
99	Entre Tabarka et le Cap Négro environ à 20 kilom. de Tabarka; Tunisie	36°58′ N.; 8°50′ E.	20. Feb. 1912	555	42	13·2	Jean Serro, mine d'Aïn Alléga par Tabarka; Tunisie	

Chart 1.



Experiment No. 1

Chart 2.



Experiment No. 2

Experiment No. 3

(bottles No. 501—525).

Liberation: Position 36° 24·5′ N.; 3° 30′ W. Date 13. May 1912, 10^{50} a. m. Wind E 2. Sea E 2.

Recovery

No. of bottle	Locality	Position (approximate)	Date	Shortest distance of drift in miles	No. of days	Average rate of drift per diem in miles	Finder	Remarks
504	Novi; Algérie	36°35′ N.; 2°07′ E.	6. June 1912 11^{00} a. m.	270	24	11·3	Emilion Courrier, Novi, Département d'Alger, Algérie	
507	Plage de l'Oued el Hachem à l'Est de Cherchel, Algérie	36°37′ N.; 2°12′ E.	6. June 1912 12^{00} m.	275	24	11·5	Georges Campagne, Cherchel, Algérie	Bonne brise d'O., grosse mer de ONO.
509	Doua Amarna, Mostaganem, Oran; Algérie	35°56′ N.; 0°04′ E.	20. June 1912	170	38	4·5	Chelich Mohamed, prés de Chéliff, Oran, Algérie	
511	Playa de Almería, 6 millas al Este, España	36°49·5′ N.; 2°21′ W.	31. May 1912	60	19	3·2	Agustin Garcia Gomez, San Jose de Cabo de Gata, Almería, España	
512	En Balerma, anejo de Dalíaz de la provincia de Almería á unos 300 metros de la Torre de Balerma, España	36°43′ N.; 2°53′ W.	29. May 1912	40	17	2·4	Serafín Martin Delgado, Balerma, España	
519	Plage St. Louis près Philippeville, Algérie	36°54′ N.; 6°53′ E.	10. July 1912	520	58	9·0	Jean Leroi, Philippeville, Algérie	

Experiment No. 4

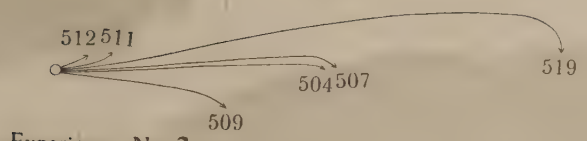
(bottles No. 526—550).

Liberation: Position 36° 42′ N.; 2° 01′ W. Date 13. May 1912, 6^{00} p. m. Wind E 5. Sea E 5.

Recovery

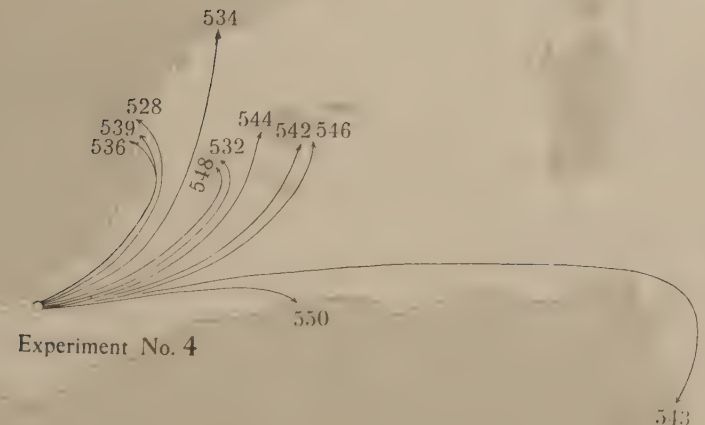
No. of bottle	Locality	Position (approximate)	Date	Shortest distance of drift in miles	No. of days	Average rate of drift per diem in miles	Finder	Remarks
528	Á 2 kilom. al N. del Faro de Canet en la orilla de la Playa	39°42′ N.; 0°14′ W.	12. Aug. 1912 11^{00} a. m.	235	91	2·6	Peregrin Senent Febrer, Puerto de Sagunto, Valencia, España	
532	Ibiza, Pueblo S. Vincente, Puerto de Punta Grosa	39°05′ N.; 1°37′ E.	8. July 1912	205	56	3·7	Pedro Ferrer, Pueble S. Vincente, Ibiza, España	
534	S. Vincente de Calders, Playa S. Salvador, Provincia de Tarragona	41°10′ N.; 1°31′ E.	24. Aug. 1912	325	103	3·2	Ramon Martorell Sales, S. Vincente de Calders, Prov. de Tarragona, España	
536	En Valencia, puesto de Garaco	39°28′ N.; 0°20′ W.	14. Aug. 1912	210	93	2·3	Salvador Ferrer, Valencia, Puesto de Garaco, España	
539	Se encontré la botella en el golfo de Valencia, á 9 millas de la costa (Valencia)	39°30′ N.; 0°07 W.	21. Aug. 1912	215	100	2·2	Salvador Cambres, Cabañal de Valencia, España	Found floating
542	En la costa levante de Mallorca, entre Cala Algar y Cala Murada junto á la costa	39°26′ N.; 3°16′ E.	11. July 1912	305	59	5·2	Jorge Perello Santandren, Felanitx, Mallorca, España	
543	Bordj-Khadidja, à la mer près Ras-Kapoudia, Tunisie	35°24′ N.; 11°10′ E.	23. Sept. 1912 12^{00} m.	750	133	5.6	Mohamed ben Ahmed Baklouti, Chebba, Tunisie	
544	Punto Qalinda, Andraitx, Mallorca, 2 millas de la costa al SE	39°34′ N.; 2°21′ E.	9. Sept. 1912	300	119	2·5	Salvador Masanet Dalman, Puerto de Andraitx, Mallorca, España	Found floating
546	3 millas de la costa levante de Mallorca presto á Puerto Colon, España	39°27′ N.; 3°28′ E.	17. July 1912 6^{00} a. m.	320	65	5.0	Jaime Alzamora, Puerto Colon, Felanitx, Mallorca, España	Found floating
548	S. José, Ibiza, España	38°55′ N.; 1°14′ E.	20. July 1912	205	68	3·0	José Mari Tur, Bagot, Ibiza, España	
550	Sur la plage de Surcouf près Aïn Taya, Algérie	36°48′ N.; 3°17′ E.	27. May 1912	255	14	18·2	Marcel Latour, Alger, Algérie	

Chart 3.



Experiment No. 3

Chart 4.



Experiment No. 4

Experiment No. 5

(bottles No. 626—650, containing sand).

Liberation: Position 36°40′ N.; 1°59′ W. Date 1. Aug. 1912, 3^{25} p. m. Wind SW 3. Sea SW 3.

Recovery

No. of bottle	Locality	Position (approximate)	Date	Shortest distance of drift in miles	No. of days	Average rate of drift per diem in miles	Finder	Remarks
627	En el mar à 6 millas del Cabo de Cala Figuera en la Isla de Mallorca, España	39°21′ N.; 2°33′ E.	26. March 1913 10 a. m.	275	237	1·2	Pedro Ferrer Siré, Palma de Mallorca, España	Found floating
628	Bordj Ounga près Maharès, Tunisie	34°23′ N.; 10°20′ E.	5. May 1913	840	277	3·0	Béchir C. Amor Haba, Maharès, Tunisie	Received too late to be inserted on Chart
637	Mallorca, proximo al Faro de Salinas; España	39°17′ N.; 3°06′ E.	3. Nov. 1912	300	94	3·2	Aurelio Fraile, Punta Salinas, Mallorca, España	
639	1 milla al O de Cartagena	37°35′ N.; 1°00′ W.	28. Sept. 1912	70	58	1·3	Matias Sedran Morena, el Portus, Cartagena, España	
642	À Kebel, côte Sud tunisienne	33°30′ N.; 11°00′ E.	31. March 1913	800	242	3·3	Khalifa ben Amor Ghoumid, Hamadi, Zarzis, Tunisie	
644	Sidi Mecheri, entre le Cap Serrat et le Cap Nègre, Tunisie	37°10′ N.; 9°06′ E.	4. Dec. 1912	560	125	4·5	M. de Lamotte, Sidi Mecheri, par Djébel Abiod, Tunisie	
646	En las playas de Algallarens en la costa Norte de Menorca, España	40°04′ N.; 3°57′ E.	12. Nov. 1912	350	103	3·4	Andrés Roselló y Galbis, Ciudadela de Menorca, España	
649	Cabezo de Cope, distrito Aguilas, una milla al mar, Murcia, España	37°26′ N.; 1°29′ W.	15. Jan. 1913	55	167	0·3	P. G. Rodriguez, Aguilas, Murcia, España	Found floating

Experiment No. 6

(bottles No. 601—625, containing sand).

Liberation: Position 37°38′ N.; 0°28·5′ W. Date 1. Aug. 1912, 11^{40} p. m. Wind SW 2. Sea SW 2.

Recovery

No. of bottle	Locality	Position (approximate)	Date	Shortest distance of drift in miles	No. of days	Average rate of drift per diem in miles	Finder	Remarks
602	En el puesto de carabineros de Calnegre inmediato á Cabo de Palos, (Murcia), España	37°38′ N.; 0°39′ W.	15. Aug. 1912	10	14	0·7	Pablo Serrano y Dionisio Valenzuel, Calnegre, Murcia, España	
607	En aguas de Calnegre en la parte opuesta del cuartel de carabineros de Puntas Cabezo de Panacro al Oeste de la Playa de Parazuelos, España	37°40′ N.; 0°44′ W.	23. Aug. 1912 10^{00} a. m.	9	22	0·4	Francisco Martinez, Mazarrón, Murcia, España	
611	La botella a sido encontrada Norte-Sul con Torrevieja, seis millas á la mar, España	37°53′ N.; 0°41′ W.	13. Aug. 1912 8^{00} a. m.	18	12	1·5	Don Antonio Serrano, Torrevieja, Alicante, España	Found floating
614	Playa de la isla Grosa, Murcia, España	37°44′ N.; 0°40′ W.	19. Aug. 1912 6^{00} p. m.	11·5	18	0·6	Julio Sanchez Grés, Cartagena, España	
615	Á 10 millas al Sur de Torrevieja, España	37°49·5′ N.; 0°41′ W.	11. Aug. 1912 1 p. m.	15	10	1·5	Fabian Serrano Andrea, Torrevieja Alicante, España	Found floating
616	Pedrucho, puesto de carabineros, inmediato al Estacio, presto á la isla Grosa, Murcia, España	37°45′ N.; 0°40′ W.	16. Aug. 1912	13	15	0·9	Benigno Torrano, Pedrucho, Murcia, España	
621	Playa del Estacio, Murcia, España	37°44·5′ N.; 0°40′ W.	14. Aug. 1912	13	13	1·0	Mauricio Fenoll, Denía, España	
622	En la playa de Guardamar, Alicante, España	38°05′ N.; 0°39′ W.	2. Sept. 1912	28	32	0·9	Manuel V. Egea, Guardamar, Alicante, España	

Chart 5.

Chart 6.

List of Papers resulting in whole or in part from the Cruises of the Danish Research-Steamer "Thor" in the Atlantic and Mediterranean.

1. Hydrography.

J. P. JACOBSEN, in Schmidt, Nielsen og Jacobsen: Fra den danske oceanografiske Expedition til Middelhavet i Vinteren 1908—1909. (Geografisk Tidsskrift, 20. H. VI, København 1910).

MARTIN KNUDSEN: Danish Hydrographical Investigations at the Faroe Islands in the Spring of 1910. (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Hydrografi, II, No. 1, København 1911).

J. N. NIELSEN: Hydrography of the Waters by the Faroe Islands and Iceland during the cruises of the Danish research-steamer "Thor" in the summer 1903 (ibid. I, No. 4, 1904).

— Contributions to the Hydrography of the Waters north of Iceland (ibid. I, No. 7, 1905).

— Contribution to the Hydrography of the north-eastern part of the Atlantic Ocean (ibid. I, No. 9, 1907).

— Contribution to the understanding of the currents in the northern part of the Atlantic Ocean (ibid. I, No. 11, 1908).

— in Schmidt, Nielsen og Jacobsen: Fra den danske oceanografiske Expedition til Middelhavet i Vinteren 1908—1909 (Geografisk Tidsskrift, 20, H. VI., København 1910).

— Sur les températures des grandes profondeurs particulièrement dans la Méditerranée, Note préliminaire, (Bulletin de l'Institut Océanographique, No. 209, Monaco 1911.)

— Hydrografiske Undersøgelser i Middelhavet; De danske oceanografiske Expeditioner i 1908—1910, København 1913.

Numerous observations, sections etc. from the "Thor" Expeditions in the Atlantic have been published in: Bulletin Hydrographique du Conseil Permanent International pour l'Exploration de la Mer, København 1902 and following years.

2. Biology.

C. H. OSTENFELD: *Thorosphaera*, eine neue Gattung der Coccolithophoriden (Berichte der deutschen Botanischen Gesellschaft, Bd. 28, Berlin 1910).

OVE PAULSEN: Plankton-Investigations in the Waters round Iceland in 1903 (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Plankton, I, No. 1, København 1904).

— On some Peridineae and Plankton Diatoms (ibid. I, No. 3, 1905).

OVE PAULSEN: Studies on the biology of *Calanus finmarchicus* in the waters round Iceland (ibid. I, No. 4, 1906).

— Plankton Investigations in the Waters round Iceland and in the North Atlantic in 1904 (ibid. I, No. 8, 1909).

— The plankton on a submarine bank (in Biologiske Arbejder tilegnede Eug. Warming d. 3. Nov. 1911, København 1911).

C. G. JOH. PETERSEN: On the Larval and Postlarval Stages of the Long Rough Dab and the Genus *Pleuronectes* (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, I, No 1, København 1904).

— Larval Eels (*Leptocephalus brevirostris*) of the Atlantic Coasts of Europe (ibid. I, No. 5, 1905).

— On the young stages of the Genus *Zeugopterus* (Report of the Danish Biological Station, XII, København 1905).

— On the Larval and Post-Larval Stages of some *Pleuronectidae (Pleuronectes, Zeugopterus)* (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, II, No. 1, København 1906).

— On the Larval and Postlarval Stages of some *Pleuronectidae (Zeugopterus, Arnoglossus, Solea)* (ibid. III, No. 1, 1909).

JOHS. SCHMIDT: Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903 (Skrifter udgivne af Kommissionen for Havundersøgelser, No. 1, København 1904).

— On Pelagic Post-Larval Halibut (*Hippoglossus vulgaris* Flem. and *H. hippoglossoïdes* [Walb.]) (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, I, No. 3, København 1904).

— The Pelagic Post-Larval Stages of the Atlantic Species of *Gadus*, Part I (ibid. I, No. 4, 1905).

— On the Larval and Post-Larval Stages of the Torsk (*Brosmius brosme* [Ascan.]) (ibid. I, No. 8, 1905).

— The Pelagic Post-Larval Stages of the Atlantic Species of *Gadus*, Part II, (ibid. II, No. 2, 1906).

— On the Pelagic Post-Larval Stages of the Lings (*Molva molva* [Linné] and *Molva byrkelange* [Walb.]) (ibid. II, No. 3, 1906.)

— On the Larval and Post-Larval Development of the Argentines (*Argentina silus* [Ascan.] and *Argentina sphyræna* Linné, with notes on *Mallotus villosus* [O. F. Müll.]) (ibid. II, No. 4, 1906).

JOHS. SCHMIDT: Contribution to the Life-History of the Eel (*Anguilla vulgaris* Turt.) (Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, Vol. V, No. 4, København 1906).

— Marking Experiments on Plaice and Cod in Icelandic Waters (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, II, No. 6, København 1907).

— On the Post-Larval Development of the Hake (*Merluccius vulgaris* Flem.) (ibid. II, No. 7, 1907).

— On the Post-Larval Development of some North Atlantic Gadoids (*Raniceps raninus* [Linné] and *Molva elongata* [Risso]) (ibid. II, No. 8, 1907).

— On the Post-Larval Stages of the John Dory (*Zeus faber* L.) and some other Acanthopterygian Fishes (ibid. II, No. 9. 1908).

— Remarks on the Metamorphosis and Distribution of the Larvae of the Eel (*Anguilla vulgaris* Turt.) (ibid. III, No. 3, 1909).

— On the Occurrence of Leptocephali (Larval Muraenoids) in the Atlantic W. of Europe (ibid. III, No. 6, 1909).

— On the Distribution of the Fresh-Water Eels (*Anguilla*) throughout the World, I. Atlantic Ocean and Adjacent Regions (ibid. III, No. 7, 1909).

— The Distribution of the Pelagic Fry and the Spawning Regions of the Gadoids in the North Atlantic from Iceland to Spain (Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, Vol. X, No. 4, København 1909).

— Exposé sommaire des travaux de l'expédition océanographique danoise dans la Méditerranée (1908—1909) (La Géographie, XXI, 2, Paris 1910).

— Leptocephalus hyoprorοïdes and Lept. thorianus (Zoologischer Anzeiger, XXXVI, No. 2—3, Leipzig 1910).

— Résultats préliminaires de l'expédition océanographique danoise dans l'Atlantique et la Méditerranée pendant l'été 1910 (La Géographie, Paris 1911).

JOHS. SCHMIDT: Biology of the Eel-fishes, especially of the Conger (Nature, vol. 86, London 1911.)

— Fünf Jahre dänischer Untersuchungen über die Biologie der aalartigen Fische (Fischerbote, No. 12, Hamburg 1911).

— Contributions to the Biology of some North Atlantic Species of Eels (Videnskabelige Meddelelser fra den Naturhistoriske Forening. Vol. 64, København 1912).

— On the Larval Form of *Chlopsis bicolor* Raf. (ibid. vol. 64, 1912.)

— Danske Undersøgelser i Atlanterhavet og Middelhavet over Ferskvandsaalens Biologi (Skrifter udgivne af Kommissionen for Havundersøgelser, No. 8, København 1912).

— Danish Researches in the Atlantic and Mediterranean on the Life-History of the Freshwater-Eel (*Anguilla vulgaris*, Turt.) (Internationale Revue der gesamten Hydrobiologie und Hydrographie, V, Leipzig 1912).

— Über die Fortpflanzung des Aals und seine Laichplätze (Fischerbote, IV, No. 7, Hamburg 1912.)

— The Reproduction and Spawning-Places of the Fresh-Water Eel (*Anguilla vulgaris*) (Nature, London, August 22, 1912).

— Sur la reproduction et les lieux de ponte de l'Anguille vulgaire (Bulletin de la Société Centrale d'Aquiculture et de Pêche, Tome XXIV, No. 9—10, Paris 1912).

— Alens fortplantning och lekplatser (Svensk Fiskeri Tidskrift, Häft I, 1913).

— On the Identification of Muraenoid Larvae in their Early ("Preleptocephaline") Stages (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, IV, No. 2, København 1913).

BJARNI SÆMUNDSSON: Oversigt over Islands Fiske med Oplysning om deres Forekomst, vigtigste biologiske Forhold og økonomiske Betydning (Skrifter udgivne af Kommissionen for Havundersøgelser, No. 5, København 1909).

Plankton.Tables resulting fom the "Thor" Expeditions in the Atlantic have been published in: Bulletin des resultats acquis pendant les courses périodiques. Année 1902—03 (supplément), 1903—04, 1904—05, København 1903—1905.

Report on the Danish Oceanographical Expeditions 1908-10 to the Mediterranean and Adjacent Seas.

No. 1 containing:

Vol. I. Hydrography I—III (complete). 1912. Price 30 shillings.

No. 2 containing:

Vol. II. (Biology.) A. 1. Flat-Fishes (Heterosomata).
Vol. III. (Miscellaneous Papers.) 1. Experiments with drift-bottles (1st Report). } 1913. Price 20 shillings.